ELEMENTARY ANATOMY AND PHYSIOLOGY

A TEXT-BOOK FOR STUDENTS IN HYGIENE AND PHYSICAL EDUCATION

BY

MARY REÈS MULLINER, M.D.

FORMERLY INSTRUCTOR IN THE SUMMER SCHOOL OF HARVARD UNIVERSITY; IN THE SARGENT SCHOOL FOR PHYSICAL EDUCATION; IN THE BOSTON SCHOOL OF PHYSICAL EDUCATION; AND IN THE DEPARTMENT OF HYGIENE, WELLESLEY COLLEGE; DIRECTOR OF THE AMERICAN SCHOOL FOR PHYSICAL EDUCATION

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PREFACE TO THE FOURTH EDITION.

In preparing the fourth edition of this book, the author has tried to profit by the constructive criticism of those who have used the previous editions.

The original plan of compiling a text that should cover the essential facts of anatomy and physiology, without a great mass of unnecessary detail, has been retained. An attempt has been made to adapt the book to the needs of those who are taking a pre-medical course. It has been found useful to medical students in reviewing fundamentals.

The insertion of additional material should render the text more helpful to the first-year student in hygiene, to the same student as he progresses through the courses leading to the degree of B.P.E., and as a reference book that is not too abstruse for ease of consultation, but is sufficiently comprehensive.

To these ends, a fuller treatment of the physiology of the muscular, nervous, circulatory, digestive, and reproductive systems, together with minor additions in anatomy, should render the book more usable and useful.

That the contents may embody the results of the latest research in anatomy and physiology, the author in preparing the text has consulted mainly the last editions of Gray's *Anatomy*, and of Wiggers' *Physiology in Health and Disease*. M. R. M.

Wellesley Hills, Mass.

CONTENTS.

CHAPTER I.

Introduction.

CHAPTER II.

The Tissues of the Body.

CHAPTER IV.

The Articulations.

CHAPTER V.

The Muscular System.

CHAPTER VI.

General Consideration of Bursæ and Fasciæ

CHAPTER VII.

The Cerebrospinal Nervous System.

CHAPTER VIII.

The Cranial Nerves and the Organs of Special Sense.

CHAPTER IX.

The Circulatory System.

CHAPTER X.

The Respiratory System.

CHAPTER XI.

The Digestive System.

CHAPTER XII.

Dietetics, Nutrition and Animal Heat.

CHAPTER XIII.

The Organs of Excretion and Elimination.

CHAPTER XIV.

The Sympathetic or Autonomic Nervous System.

CHAPTER XV.

The Ductless Glands.

CHAPTER XVI.

The Reproductive System.

ANATOMY AND PHYSIOLOGY.

CHAPTER I.

INTRODUCTION.

The Approach.—The study of the anatomy and physiology of the human body presents various difficulties that are not inherent in the consideration of many other sciences. Our living body is a complete organism, with no really satisfactory method of approach or building-up that will enable us to comprehend clearly the relations of parts, or their interdependence. Paradoxical as it seems, some knowledge of all the parts of the body is a necessary preparation for beginning the study of its anatomy and physiology. When such a study is completed, one is ready to begin to learn something about it.

In this lack of a beginning, anatomy and physiology differ widely from the first steps in the "Three "R's." Adding one and one is a simple preliminary to a grasp of mathematics; recognizing "a" and "b" precedes all reading, etc., but there is no simple formula which can be said to lead up to the study of our own bodies.

It may be claimed that the study of embryology is just such a simple beginning. But, as the complicated cell is considered and its multiplication followed we find the beginning of this, that and the other layer which develops into such and such structure. In the absence of any knowledge of structures, these terms have little meaning. Evidently, the clear-cut approach is not through the embryo.

A more practical method involves the consideration of the body as consisting of many parts, none of which is autonomous, but *all dependent on every other*; looking at it as a contrivance by which adjustment is made to the environment; and seeing it as a mechanism by which Nature preserves the individual and perpetuates the species. This may be the best way in which to illumine the subject, as they are manifestations of life.

Three Essential Manifestations of Life.—By one of the simplest forms of life three of these essentials may be illustrated.

The Amœba.—The amœba (a small mass of living matter having a more solid spot called the *nucleus*), may be found floating in

stagnant water. This irregularly shaped mass can throw out a long process to which the rest of the mass can draw itself. It possesses the power of motion. If, in the course of apparently aimless movements it contacts some other substance, the processes may surround or enclose it. If the material is suitable for food it is taken into the amœba's substance, becomes a part of it, and adds to its size. If it is unsuitable for food, the amœba unwinds its processes and floats off to find something else. It has some selective sense, as well as the ability to digest and grow. As the organism grows, the nucleus and mass divide into two parts, which are then two individuals with the same life history. (Fig. 1.)

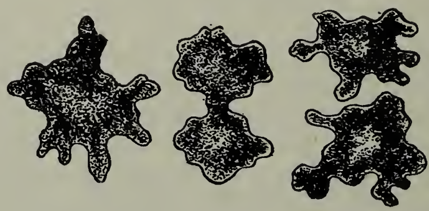


Fig. 1.—Amœboid movements. (Häckel.)

Here are seen the life manifestations of adjustment to the environment; nutrition and growth with interdependence of parts; the survival of the individual, and the perpetuation of the species.

The Survival of the Individual.—The life history of the amœba differs from that of man only in degree. Man survives only as he can make continuous and adequate adjustments to his environment.

These environmental factors include variations of temperature from 60 degrees below zero to 130 degrees above; density of air ranging from that in the deepest mines to the rarefaction of the stratosphere; movements of air from stagnation to hurricanes; and humidity from saturation to aridity. All sorts of irregularities and obstructions on the earth's surface present pitfalls; sounds, terrifying or pleasant impinge upon the sense of hearing; odors, repulsive or appetizing serve as warnings, while multitudinous materials with varying tastes offer pleasure or destruction. Enemies, human or animal, threaten his life. By man's ability to make adjustments to these conditions, he lives or dies.

The Mechanism of Awareness.—Knowledge of the surroundings comes through an intricate system of nerves which informs the conscious brain. The appropriate re-action to this information comes through an intricate system of nerves carrying orders from the conscious brain to various structures of the body.

Foundations of These Structures.—All organisms imply some framework to support softer parts. This gives form. In vertebrates the chief firm framework is called the bony skeleton. This is

encased by many other parts, holding them so they do not interfere with others equally important. Cavities of bone contain and protect the brain, spinal cord, abdominal and pelvic organs, heart and lungs. Bones give attachment to muscles, providing leverage for their action with resulting movement of the various segments of the body.

Holding the bony framework together is a softer tissue called fibrous which forms the support of the organs that have the laboratory work of the body. Even microscopic cells rest in a fibrous network, while the blood-vessels and nerves are incased therein for protection and support.

Thus the framework is in relation with all the other parts which are interdependent. So complete is this arrangement, if every other structure were removed, the outward form of the body would still be preserved.

Means of Motion.—In the adjustment of the organism to its surroundings motion is necessary. The bones of the framework are united yet they can be moved at the joints with considerable freedom, but only by means of more active substances. These active substances are muscles, with their special function of contractility. By shortening the distance between their attachments on two bones, motion of the bony skeleton is produced, such as stepping, running, jumping. Numberless motions of the arms, hands and trunk are possible as the conscious mind gives orders to these muscles.

By their activity much of the bodily heat is developed, along with waste materials. Muscles have an important part in the mechanics of the blood circulation, as their contraction produces the suction force necessary to move the blood back to the heart after it has been sent to the periphery. A large proportion of the blood is distributed to the muscles.

As some muscles obey the will there needs be lines of communication to carry the orders, without which they are useless. These lines are nerves. However, there is other motion going on in the body, than that which is under the control of the will. In the walls of the blood-vessels; in the walls of the stomach and intestines; and in the heart, are muscles that cause rhythmic movements, and so help carry on the functions of these parts as well as that of all others. According to the needs of the tissues these contractions are regulated by a part of the nervous system, which determines how much blood shall pass through a vessel at any time, and thereby controls the amount of activity with which the work of the body shall be done.

Though the muscles are sometimes considered as only making a more or less shapely form, their importance in the real work of the body is second to none. They link the mechanical structures with those that seem more vital.

The Centers of Power.—As every business requires a directing head, so the human body must have what may be compared to power stations. The great central authority is the brain, the seat of the mind and the will. Here, messages come in from all parts of the body, and orders go out. Information as to environment, with the appropriate re-action orders, are carried by the extensions of the brain called nerve fibers.

Messenger Service.—By means of these we see, hear, feel, taste, smell, and re-act to the information so brought to the brain. There is no part of the body that is not in communication with the brain; no part is living for itself alone. A part dying starts the process of dissolution for all. One tissue, one organ, becoming diseased, starts a vicious circle that presently involves all in destruction. Increased vigor in one tissue may start a healing process that will renew the whole body. Every tissue, every cell, lives for all the others.

In addition to the brain, there is a part of the nervous system which must activate the body cells that have to do chemical work, such as secreting gastric juice, saliva, etc. This is called the sympathetic or autonomic system. It is the "go-between" for the subconscious self and the tissues, or the physical representative for what has never been definitely determined to have a local habitation. This system of nerves is widely distributed, but the greatest masses are in the abdominal cavity. Some of these are known as the *solar plexus*, the *renal*, the *aortic* plexi, etc. Smaller masses are placed in front of the spinal column. The name, "abdominal brain" is sometimes given to these nerve collections, but it is not fully descriptive. We know little of how to affect this system, but there is, without doubt a close relationship between the conscious mind and that which regulates this other essential part of living.

Regulators.—Another set of organs that may well be classed as among the controlling centers are the ductless glands, or the endocrines. They secrete potent materials from the blood, and allow them to return to the blood stream. These secretions determine growth and development, of both body and mind, the full extent of which is at present unknown.

Building and Repair Materials.—All organic structures must have building material for new construction, repair material for broken-down parts, and raw material for the peculiar kind of work to be done. The body does much mechanical work such as moving; it does chemical work with the production of heat and energy; it transforms and elaborates materials into various other forms. This all means oxidation of tissue with some destruction. If the tissue is not renewed death would result. The rate of repair must correspond with the rate of loss. These repair materials thus used are provided in the shape of food from outside the body.

That this food may be taken up and used by the cells of the body,

an elaborate system of organs, the digestive system, is concerned in preparing it. This process includes such mechanical preparation as grinding and mixing; such chemical work as the formation of reagents from the blood which act upon the food, utterly changing it in form and texture so it may become fit to be used as building material. Some of the organs concerned are the teeth, stomach, intestines, liver, pancreas, etc., forming a long tube with accessory laboratories.

Another element needed in the tissues is oxygen. This enters the body through the respiratory system. It is a constituent of the blood.

The Common Carrier.—After the food materials are prepared to become a part of the tissues, they must be carried to them *via* the blood stream. This is done by a system of tubes, called blood-vessels which serve as the roadway while the motive power to carry the blood from place to place comes from two pumps, one a force pump, the other a suction pump. The tubes vary in size from a diameter of 1 inch to a small fraction of an inch, or too small to be seen without the aid of a microscope. Wherever the tissue cells are, the blood-vessels are also found, so every part of the body is supplied with them. The food materials are thus carried to the various cells where they form part of their structure. They produce energy in the form of heat, motion, or thought; they re-build cells, form substances for the digesting of other foods as well as making numerous other things needed in the organism.

The Great Laboratories.—In the blood carried by the tubes, in addition to the digested food products, there are certain débris resulting from the work of the cell. This is the waste which if not removed would poison the body. By the normal activity of these laboratories enough waste is continuously removed to keep the remaining quantity below the "danger line." The organs of excretion, as the kidneys, liver, skin, bowels and lungs, have this important function in charge. The survival of the organism is very closely associated with the normal functioning of these organs.

Two kinds of materials are handled in this process. First, The carbon dioxid which is produced during the combustion of carbon in the tissue cells. As in a stove, when carbon in the form of coal is burned, heat is given off, as well as carbon dioxid with a residue of ashes. When carbon is burned in the body, during the work of the cells, heat or some other form of energy is released, and the usual waste is left. As this is well known to be poisonous, it must be removed. The lungs are the organs by which an exchange is made between the oxygen of the outside air and the carbon dioxid in the blood. This is called "aerating the blood." It is not a purifying process.

The second kind of waste produced by the breaking down of the cell structure during its work contains a number of substances

prominent among which is nitrogen, This gives the name of "nitrogenous" to these waste products. They are filtered from the blood in the liver, kidneys, bowels, and skin. This *purifies* the blood, and it is the only process that should have this name.

Perpetuating the Species.—So far the reaction of the organism to its environment has been to preserve the individual. From Nature's standpoint it is just as important to perpetuate the species. When the organism has become full-grown or mature certain organs, though present at birth, are ready to take on activity. They are the "reproductive organs" distinguishing male and female, and through their functioning new units are developed. The age of "puberty" (about thirteen years in temperate climes), marks the time when this function becomes possible, though not desirable. Secretions from these organs, apparently, are necessary for the proper development of the entire organism during the years of adolescence. (From the twelfth to the twenty-fifth years.)

With this description of the foregoing organs which are concerned in the life processes, it must also be realized that the events do not take place in a way that can be followed by the unaided senses. The ultimate units of the various tissues are microscopic cells.

In cells, contractions occur; food products are elaborated or broken down; many chemical changes take place, and electrical currents are generated. Cells carry oxygen in the blood stream.

All this work is done in or by cells, while in the final processes of reproduction the cell is magnified and brought to its greatest development.

With this preamble, the possibility of seeing how all parts of the body are inter-related and interdependent, may open the subject of anatomy and physiology.

Definitions.—*Anatomy* may be defined as the science that treats of the structure of organized beings. Organized refers to that which has distinct and different parts as compared with those that are all alike. Metals, minerals and chemical substances in general are inorganic. Plants and animals have organs, which are essential parts, no matter how few and simple they may be. *Animal anatomy,* or *zoölogy,* includes the structure of human beings and of the lower animals, as distinguished from that of plants or *botany.* The subdivisions of zoölogy are called *human anatomy* and *comparative anatomy.*

Physiology refers to the study of the functions of the organs in animals.

The study of anatomy doubtless goes back to the infancy of the race. Every child is curious as to how things are made, and with adults the natural horror of death would be overcome by the desire to see what was inside the skin of a dead body.

Names.—As bodies were examined, the various parts were given names, many of which survive to this day. These names are not always properly descriptive, as might be the case if the parts were to be named in the present state of knowledge. They were often given on account of a fancied resemblance to familiar objects, as in calling the cavity in which the head of the femur rests, at the hip-joint, the *acetabulum* or vinegar cup, etc. When some individual studied and described a part, that had not been known before, the name of that person was tacked on, as *Eustachian canal, Poupart's ligament,* etc. These methods make it difficult sometimes to give a reason for terms, so we must fall back on the statement that certain parts are called in a certain way because they always have been so called.

Anatomy of the Lower Animals.—In beginning the study of human anatomy, it is a great help to utilize the lower animals. Specimens from the bodies of cats, chickens, lambs, etc., are invaluable in studying the tissues, as they are identical in appearance and structure with those in the human animal. Even the viscera of the cat bear a sufficient resemblance to those of man to form a most useful preliminary study.

Divisions of Anatomy.—Anatomy is studied either as the gross structures present themselves or with the help of a microscope in prepared sections. This latter method is called *microscopical anatomy* or *histology.* The study of the relations of one part to another is called *regional or relational* anatomy. Considering the body as made up of organs, its study is called *systematic* or *descriptive* anatomy. It may be considered with regard to the needs of the surgeon or physician, as *surgical* or *medical* anatomy. *Pathological* anatomy treats of the diseased states of the body and the structural changes produced. *Artistic* anatomy interests the artist, while *applied* anatomy by tracing the actions of various muscles used in walking, throwing, etc., is essential to the work of the student in physical education.

The dissection of a body, that is, the careful cutting apart of its various structures is essential to study of its *anatomy.* The use of the roentgen rays is a modern development in scientific study, and has the advantage of showing some things that cannot be seen except during life.

Physiology is studied by inference from dissections, by observation in the living body, and more especially by experimentation on animals, and human beings.

The parts of the body are given technical names, mostly Latin. They also have popular or vernacular names, which may carry a different meaning. To a layman, *leg* refers to the entire lower extremity, but to a medical person, it means the segment between

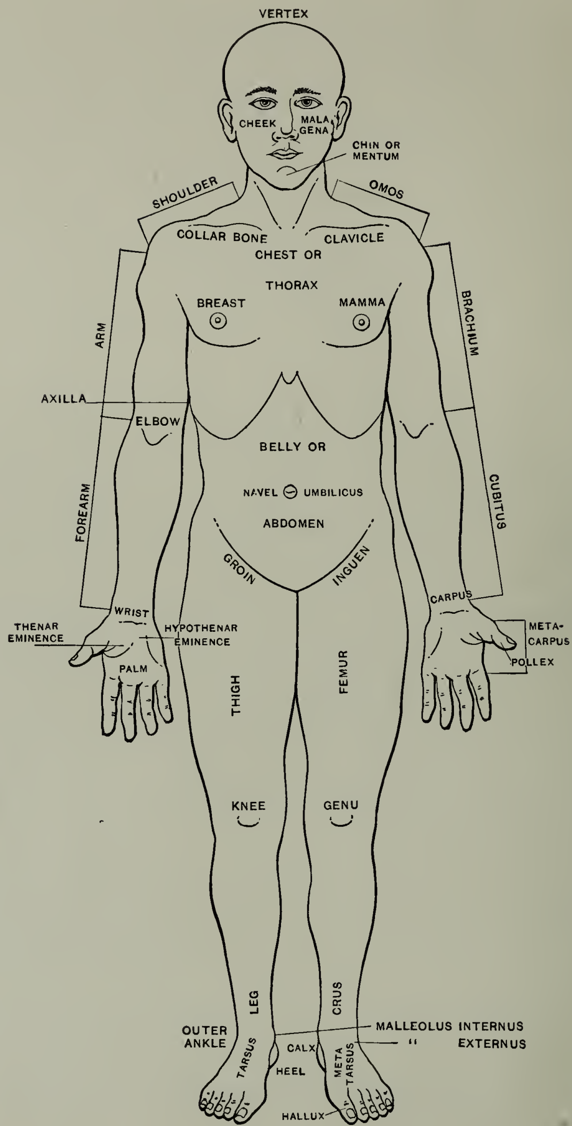


FIG. 2.—English names on left side. Latin names on right side.

the knee and the ankle, only. In the use of anatomical terms care should be taken that they be scientifically correct, even at the risk of seeming pedantic. And, they should be spelled correctly!

The Anatomical Position.—The anatomical position, in which the body is studied, and on which descriptions are based is standing,

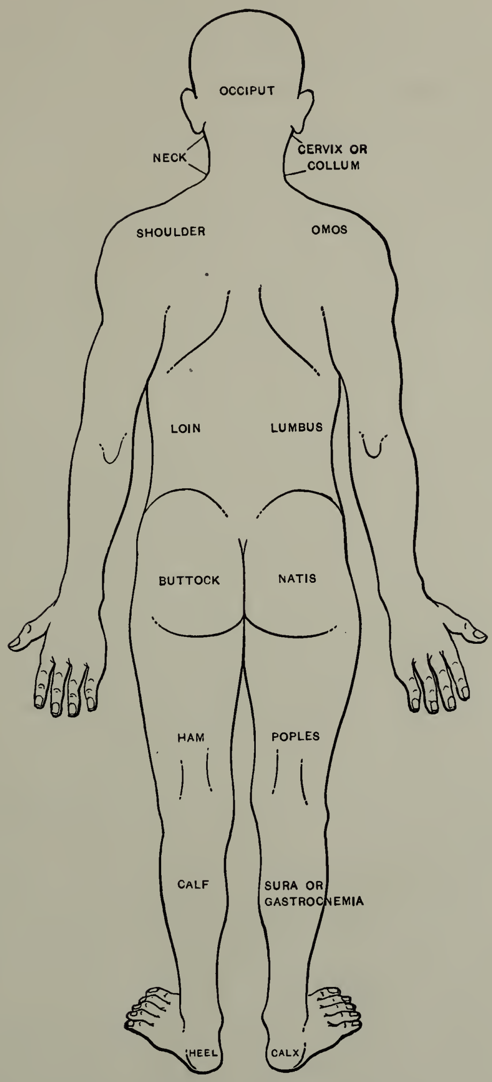


Fig. 3.—English names on left side. Latin names on right side.

with the arms at the side, and the palms of the hands facing forward. (Figs. 2 and 3.)

The Planes of the Body.—In that position, it is possible to consider the body as being divided by three planes. The *sagittal,* a vertical cut through the middle from front to back, divides the body into right and left halves. The *coronal* or *frontal,* a vertical cut from one

side to the other side, divides the body into anterior or ventral, and posterior or dorsal parts. The *transverse* or *horizontal* section, is on a level with the horizon, and may be made at any height.

A sagittal plane is a mesial plane, and descriptions of parts refer to their relation to that middle line, or plane. Toward it is mesial or medial; away from it is lateral. Dextral refers to the right side, while sinistral refers to the left.

The transverse planes divide superior or upper parts from inferior or lower ones. Proximal refers to that which is nearer the medial or the superior part, while distal has the opposite meaning.

General Description of the Body.—The *caput* or *head* is divided into the *cranium* and the *face.* Subdivisions of the cranium are the occiput at the back, the forehead in front, the sinciput at the vertex, and the temples at the sides. The face includes the chin, cheeks, nose, eyes and mouth.

Below the head is the neck (*cervix* or *collum*), which connects it to the trunk. The front is called the throat, and the back of the neck, the nape (*nucha*).

The *trunk* is divided into the upper portion or chest (*thorax*) and the lower portion or belly (*abdomen*). The line of demarcation between the two is the lower border of the ribs and the lower end of the sternum, on the surface. Within, the floor of the thorax and the roof of the abdomen is formed by the diaphragm, a dome-shaped muscle. As this dome projects into the upper cavity, the thorax is smaller than appears on the surface, and the lower cavity is much larger. On the chest is a rounded mound, called the *breast* or *mamma,* much more pronounced in women than in men. About the middle of the abdomen is a puckered depression, called the *navel* or *umbilicus.* This is the scar produced by severing the umbilical cord after birth.

Projecting from the trunk are two upper extremities and two lower. The *upper extremity* presents four segments, in the following order: shoulder, arm, forearm and hand. Separating these are the shoulder-joint, the elbow-joint and the wrist-joint, in the order from above downward.

The *lower extremity* also presents four segments; hip, thigh, leg and foot. These are separated by the hip-joint, knee-joint and ankle-joint in the order from above downward. The hip serves as a part of the wall of the abdomen, while posteriorly on the same level, is a rounded mass of muscle and fat called the buttock (*natis*). Back of the knee-joint is a lozenge-shaped space called the ham (*poples*), with the cords or tendons on the inner and outer sides known as the *hamstrings.*

By reference to Figs. 2 and 3, other details of surface parts may be seen, with their English and Latin names.

PROPERTIES OF A LIVING BODY.

The principal facts in anatomy have been obtained by the study of the cadaver or dead body, but those of physiology have been learned from the living body. There are similarities between these two, but some essential differences which should be considered here.

First, in the matter of consciousness. The dead body has absolutely no consciousness of its surroundings, and at times a living body seems equally so. A person in a faint is oblivious to everything about him, but sooner or later he comes out of the faint and is more or less conscious of what is going on about him. So, a living body is said to possess more or less consciousness.

Next, the living body may feel cold, but it is not of the same temperature as its surroundings, which does characterize the dead body. A temperature of 30° F. in the surrounding atmosphere would freeze a dead body, so it would register the same. But, the living body would maintain a relatively high temperature under the same conditions, and would register about 98° F. This would be no more if the surrounding temperature went to 110° F. The temperature of the living body would not go up to correspond, but would remain at the normal.

Third, we may command the dead body to move, but it neither hears nor obeys. We may use electrical stimulation but no response is obtained. The body remains perfectly inert. But even when the living body is unconscious it still possesses the *power* of movement, of spontaneous movement, and it will respond to electrical and other stimuli.

These essential properties of the living body enable it to adjust itself to its environment. In anatomical terms they are

1. Irritability, or the power to respond to external stimuli.
2. Contractility, or the power to move from place to place.
3. Metabolism, or the power to take in food, build it up into its own structure, and thereby grow, as well as eliminating the waste products.
4. Function, or the power to do some sort of work.
5. Reproduction, or the power to make new individuals of its own kind. These are fundamental in every living body, and in the minute divisions of the body.

By the aid of the microscope, it has been found that we are made up of numberless minute cells, each of which possesses the above properties to a greater or less degree. While the cell cannot be considered the *absolute* unit of body structure, it forms a practical basis for study. The investigation of the ultimate subdivisions, the *atom* and the *electron*, bids fair to shed much light upon the physiology of the body.

THE CELL.

There is now to see just what is meant by a cell, and it may be briefly defined as a *minute mass of protoplasm, with a nucleus.* It may or may not have a cell wall; it may or may not have one or more nucleoli.

The essential parts are the living protoplasm, and the nucleus, When examined during life, protoplasm, the physical basis of life. is a jelly-like material. It is difficult to determine its structure as the process of preparing it for microscopic examination kills it.

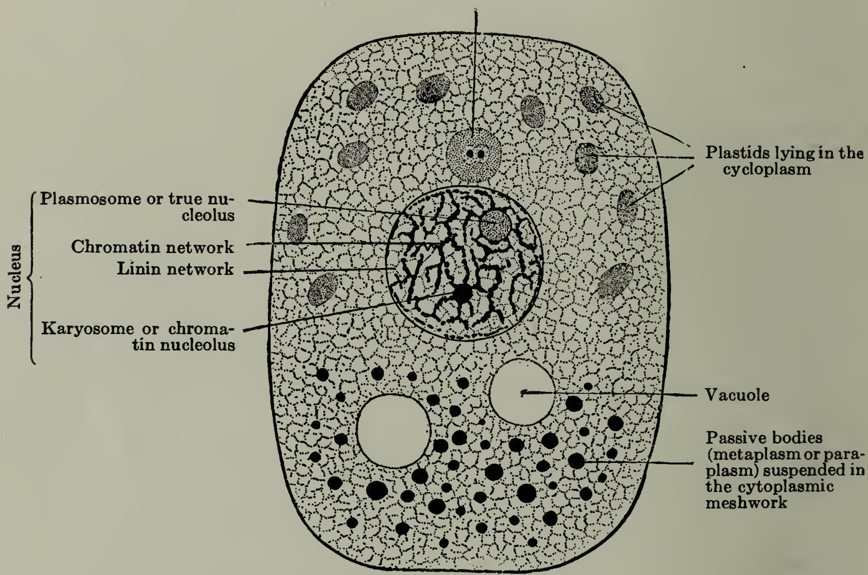


Fig. 4.—Diagram of a cell. Its basis consists of a meshwork containing numerous minute granules (*microsomes*) and traversing a transparent ground-substance. (Wilson.)

There may be a network of fibers with the fluid portion contained in it, and the nucleus may also have a network. It may be the protoplasm is granular, or the granules seen in working cells may be material that has been taken in to be used to make the peculiar secretion of the cell. As no reproduction can take place without it, the *nucleus* is essential to a living cell.

Chemically speaking the contents of the cell are: Water, salts and organic substances. There are twelve salts in the body, the most plentiful of which is sodium chloride. The inorganic substances consist of a little phosphorus, some sulphur, carbon, hydrogen,

oxygen and nitrogen. The last four are combined with protein. Apparently, very little or no carbohydrate or fat is present.

A typical cell is spherical in shape, having a thickened portion, the nucleus, near the center, with the nucleoli showing as darker spots in the nucleus. Near the nucleus or in it is a small spheroidal body called the centrosome. This shows rays proceeding from its center. The centrosome divides in making new cells. A single cell may form a unit of life, as in the amœba. As the aggregation and differentiation of cells proceed, the organism becomes of higher grade.

The Origin of Cells.—Cells are always derived from cells, so the beginning of existence must have been as a cell. This cell is called the *ovum*. In some degree, all the properties of life are possessed by the ovum. After it is fertilized it divides and subdivides until a large number of cells are formed.

Differentiation of Cells.—As the cells increase in number, they separate into layers that have some function especially developed. That is, certain cells are called upon to specialize in contractility, others in irritability, others in secretion, etc. The process is comparable to a community in which every individual must eat, have shelter and be clothed, and where instead of each one getting his own food, building his own shelter and making his own clothing, certain ones do all the work connected with the food; others do all the building, and still others have charge of the clothing. So the various needs of the community are met by the specialization of its members, with the work done more perfectly. The higher the scale of civilization, the more one sees of such limitation of work to one kind. The higher the grade of living beings the more definitely the cells are specialized, and the more impossible it becomes for different kinds of cells to exchange work.

Aggregation of Cells.—In the developing human embryo the first aggregation of cells is into three layers, from which by further and constantly increasing differentiation are finally developed all tissues and organs. Each layer gives rise to its own particular group of tissues.

The Intercellular Substance.—The cell is the actual working unit of the body, and from it is developed a substance that lies outside of it, known as the *intercellular substance.* This varies in amount, sometimes being only enough to unite the cells or it may predominate as in some forms of connective tissue. The greater the proportion of cells to intercellular tissue, the more active is the tissue.

Tissues.—The association of a particular type of cell with a particular type of intercellular substance is called a *tissue.* The association of tissues to form a definite structure, to perform some definite function, is known as an *organ.* The association of several organs to perform some definite work, is known as a *system.* For

instance, the teeth, stomach, liver, pancreas and intestines are organs that help to form the digestive system.

QUESTIONS.

What is the "anatomical position?"
What constitutes the framework of the body?
Why should the body require "food?"
What is the relation of the bloodvessels to other parts of the body?
Can you compare the body to a furnace? If so, how?
How do animals differ from plants?
What is the unit of body structure?
What is a "cell?"
Which of the fundamental properties of a living body do cells possess?
Do all cells possess these properties in equal degree?
What is differentiation of cells?
What is a tissue?
What is "amœboid" motion?
What is "life?"
What functions are the parts of the body designed to fulfil?

CHAPTER II.

THE TISSUES OF THE BODY.

In spite of the great variety of appearance of different parts of the body, they may all be grouped under five heads as belonging to five separate tissues.

Connective tissue is the lowest grade and has much intercellular material with few cells.

Epithelial tissue, the next higher grade has little intercellular substance with many cells.

Blood, the liquid tissue has about an equal division of cells and intercellular substance.

Muscular tissue has little intercellular substance.

Nervous tissue has little intercellular substance. With muscular tissue it is the highest grade tissue in the body. The place of an animal in the scale of existence is determined by the extent and complexity of its nervous system.

The Shape of the Cells.—In the different tissues the shape of the cell is modified by the work performed. In other words, *function determines structure, and structure determines function.*

The typical cell is a spherical mass. In epithelial tissue this is modified by pressure, into many forms. In muscular tissue it develops into a long cylindrical cell, more like a section of cord, and suitable for pulling on the bones. In nerve tissue where there must be intimate communication between the various cells, there are many processes or branches. In the liquid tissue, the solid cells must float in the liquid, so these are either spherical or flattened like disks.

THE SUSTENTACULAR TISSUES.

1. *Fibrous.*
   - White fibrous tissue (connective tissue proper).
   - Yellow-elastic fibrous tissue.
   - Areolar tissue.
   - Adipose tissue.
   - Gelatinous tissue.
   - Adenoid reticular tissue.
   - Neuroglia.
2. *Cartilaginous.*
   - True hyaline cartilage.
   - White fibrocartilage.
   - Yellow fibrocartilage.
3. *Osseous.*
4. *Dentinal.*

The above are the mechanical tissues, or those that support all the other kinds. There is no part of the body into which the sustentacular tissues do not enter, so that if every other tissue were removed the shape of the body would remain exactly as it was before.

White Fibrous Tissue.—The framework of bones serves to support the muscles and enclose delicate organs. The cartilaginous material pieces out some of these uses, besides making the joint surfaces smooth. But the fibrous form of connective tissue, binds muscles to bones by tendons; binds bone to bone, by ligaments; covers and unites muscles, by fascia; forms the framework for all the organs of the body and with a fine mesh sews everything together.

If you can get a piece of the small end of a leg of lamb, such as the butcher usually throws away, you may see several of the forms of

Fig. 5.—White fibrous tissue. (Gerrish.)

Fig. 6.—Cells of white fibrous tissue, often called connective-tissue cells. (Gerrish.)

connective tissue. Or the leg of a chicken will do equally well. On the outside of the meaty part (which is muscle), you will notice a white covering which is very tough. It is difficult to detach from the flesh, and if you tease it with a fine needle, it is seen to be made up of fine white threads woven into a sheet.

This is *white fibrous* tissue, very strong, flexible but *not elastic.* It is used where these qualities are required as in tendons, which unite muscle to bone; in ligaments which unite bones to bones at joints; in sheaths that cover muscles as fascia, dipping down between them as intermuscular septa; in the capsules that cover various organs, holding them firmly and in their own place, and forming shelf-like processes which support organs like the liver and intestines. White fibrous tissues forms a part of the covering of bones, as periosteum. By cutting down on the specimen from the butcher you

may see how strong it is and how closely applied. Under the microscope, fibrous tissue is found to consist of very fine fibrils, placed side by side in wavy bundles. A few cells are present, but they do not appear unless the preparation is suitably stained. (Fig. 5.)

Yellow Elastic Tissue.—This is the fibrous tissue that is strong, flexible *and* elastic. It is not fitted to be used in tendons, because it would allow the bones to get out of place during muscular contractions. It is useful in places where it is necessary to have parts return to their original position after being moved away. It is combined with cartilage in the *pinna* or *external ear,* and is plentiful in the ligamentum subflava, connecting the laminæ of the vertebræ.

Microscopically, yellow elastic tissue consists of rather thick and branching fibers, which curl up at the ends where they are broken. (Fig. 7.)

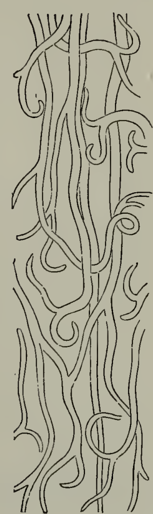


Fig. 7.—Yellow fibrous tissue. (Queckett.)

Areolar Tissue.—If the student will now take the fragment of meat, referred to, and gently pull the fibers apart, it will be seen there are numberless very fine threads holding them together. The threads resemble a spider's web for fineness and delicacy, and on looking carefully, they can be seen everywhere sewing together the larger elements.

Minute spaces between the threads give the name to this tissue though these are not definitely walled. They communicate freely with each other and are bathed in a lymph fluid which increases their flexibility. (When any part of the body is injured, the swelling which follows is usually due to the increase of fluid in the areolar spaces.)

Areolar tissue is found under the skin, connecting it with the underlying tissues; forming a bed for bloodvessels; a bed for nerves; among bundles of muscle tissue; and in the spaces about other kinds of cells, as in glands. It is attached to deeper structures on one side and to the superficial structures on the other. When one of these is moved the areolar tissue allows it to slide for a short distance, by stretching the yellow-elastic fibrous tissue and straightening the wavy bundles of the white fibrous tissue. The skin may be pulled quite a distance and then return to its former position by the yellow elastic fibers drawing the white bundles back to their wavy condition.

The microscopic appearance of areolar tissue, as illustrated, shows a combination of white fibrous bundles and yellow elastic fibers in a network around it. (Figs. 8 and 9.)

Adipose Tissue.—This is a modification of areolar tissue, in which the spaces are filled with oil or fat. The connective tissue cells

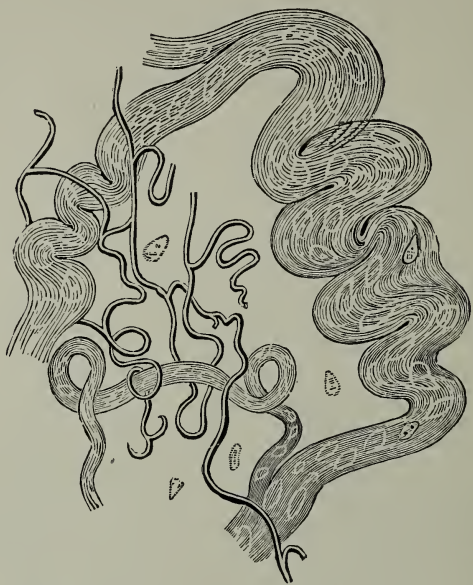


Fig. 8.—Areolar tissue, composed of bundles of white fibrous tissue and branched strands of yellow fibrous tissue loosely intertwined. (Gerrish.)

undergo a degeneration or metamorphosis in which little sacs of oil are formed which are deposited in the areolar spaces. This

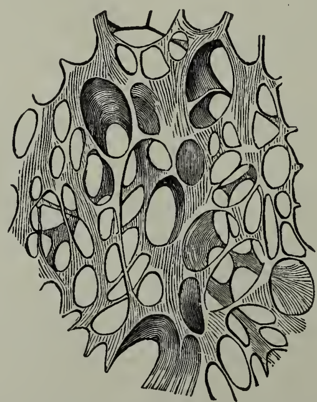


Fig. 9.—A portion of areolar tissue inflated and dried, showing areolæ. (Gerrish.)

tissue is practically everywhere, with a few exceptions. It varies in amount, and is sometimes present to a dangerous degree. Fat

serves as a cushion for organs, as the eyeball and kidney; a protection against cold; it is a slow conductor of heat; as a reserve supply of food. It adds grace to the form by rounding out what would otherwise be angles.

Gelatinous Tissue.—This is an immature form of fibrous tissue consisting of a network enclosing a semi-fluid material. An example of this tissue is the *vitreous humor* of the eyeball, which maintains the shape of that organ to prevent the wrinkling of the retina, with consequent blurring of the vision.

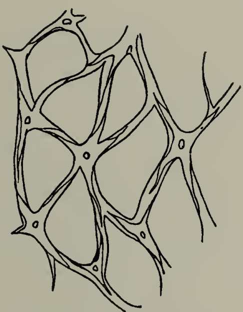


FIG. 10.—Adenoid reticular tissue. (Gerrish.)

Adenoid Reticular Tissue.—This form of fibrous tissue serves as a framework for the irregular masses of leukocytes (white blood corpuscles) which are the active portions of lymphatic nodes, sometimes called lymphatic glands. It is also plentiful in mucous membranes. (Fig. 10.)

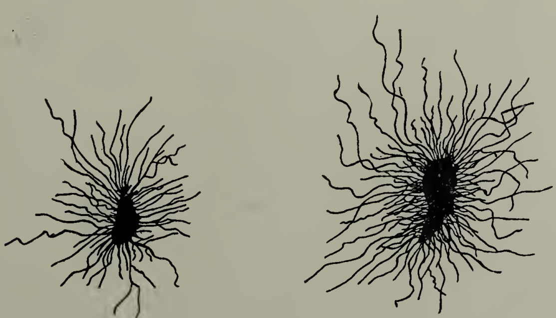


FIG. 11.—Neuroglia cells. (Gerrish.)

Neuroglia.—This is a network that supports the nerve substance of the brain and spinal cord. It is not true white fibrous tissue, but is made up of glia cells and their branching processes. These cells are irregular and star shaped with their branching ends frayed out in minute fibrils which go everywhere between the nerve cells and the fibers. (Fig. 11.)

Cartilaginous Tissue (Hyaline Cartilage).—This is composed of a very few cells and much intercellular material. It is bluish-white, dense, smooth and elastic. It covers the joint surfaces of all bones, serving as a buffer and lessening friction; it is placed between bones as a buffer; it connects the ribs with the sternum, adding much elasticity to the thoracic cage; it forms the larynx and most of the nose; and it is the material which keeps the trachea and bronchi from collapsing, so the air may pass through without hindrance. It is covered with a protective and nutritive coat, called *perichondrium.*

White Fibrocartilage.—This is a combination of hyaline cartilage and white fibrous tissue. It is tough, elastic and flexible, and is used to give elasticity to certain structures, as when placed between the bodies of the vertebræ as the intervertebral fibrocartilages.

Yellow Fibrocartilage.—This is a combination of yellow elastic tissue and hyaline cartilage. It is markedly more elastic than hyaline cartilage. It is used to form the epiglottis, and the pinna.

Hyaline cartilage is either temporary or permanent. In fetal life, the long bones are laid down as rods of cartilage. Later as the bone-salts are deposited in them, the cartilage is replaced by bone. This is the temporary form.

The cartilage on the articular surfaces of bones is always cartilage, and undergoes no change.

Osseous or Bony Tissue.—Osseous or bony tissue forms the fundamental framework of the body to give it stability. Cavities for the reception and protection of the most delicate organs, as the eye, brain, spinal cord, and lungs, are made by bone. In addition, they give attachment to muscles.

It is the form of connective tissue that is of the hardest consistency, being exceeded in hardness by two materials only, the dentin and enamel of the teeth. The hardness of bone is due to the deposition of inorganic substances in the intercellular matrix. These materials are mainly the phosphate and carbonate of lime, though small quantities of other salts are present. These salts are so intimately combined with the osseous structure that though they compose two-thirds of the weight of the bone, they cannot be distinguished as separate even by the use of the most powerful microscope.

Bone consists of animal and mineral matter, 36 per cent of the former and 64 per cent of the latter. When the animal matter has been burned out, the bone remains of the same shape, but is very brittle, crumbling easily. If the mineral matter is removed by soaking in dilute acid, the shape is not changed, but it has no rigidity. It may be bent and twisted in any direction. The appearance under the microscope remains the same in both cases.

Recent Bone.—If the specimen of bone from the butcher is examined, it will be noticed that the bone is pinkish in color, is covered with a thin membrane (the periosteum), and the sawed end shows it to be a hollow cylinder. A pinkish material is in the center (marrow), but if the bone is mature this marrow is yellow. If the specimen is dissected and the joint end exposed, it will be seen to be covered with an opaque, bluish-white material which is cartilage. A thin slice of this may be cut off and examined.

Now, if the enlarged end is sawed through, it apparently consists of a spongy structure (cancellous bone), with the spaces filled with a pinkish (red) marrow. (See Fig. 12.)

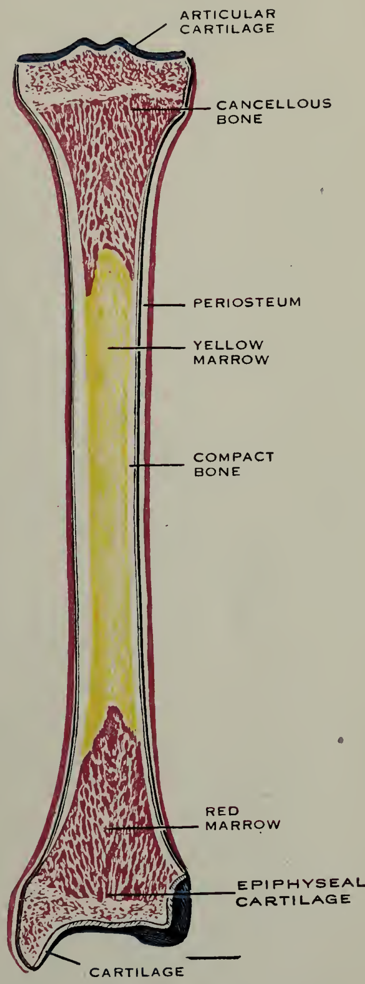


Fig. 12.—Diagram of recent bone.

Comparing this bone with that of the cylindrical end, it is evident that bone exists in two forms. On the outside of the bone and forming the hollow shaft the bone is very solid. This is *compact* bone, very strong and heavy. If the entire bony skeleton were of this compact bone, our weight would be so much increased it would be necessary to have much larger and stronger muscles to move the body. To secure the necessary strength without undue weight, the shafts of the long bones are hollow and the expanded ends are made of cancellous or spongy bone which is very light in weight.

The specimen from the butcher shows bone as it exists in the body, the so-called "recent state." The dry bones generally used in the study of anatomy, have had all the soft tissues removed, making them much pleasanter to handle.

It is in the minute structure that the essential life of bone is carried on. Like the other forms of connective tissue it is made of cells and intercellular substance, of which the latter predominates. The working part or cells are ovoid in shape, nucleated and with numerous small processes. These cells lie in spaces called *lacunæ* (little lakes). From the lacunæ pass minute canals (*canaliculi*) which join with those from other lacunæ, so there

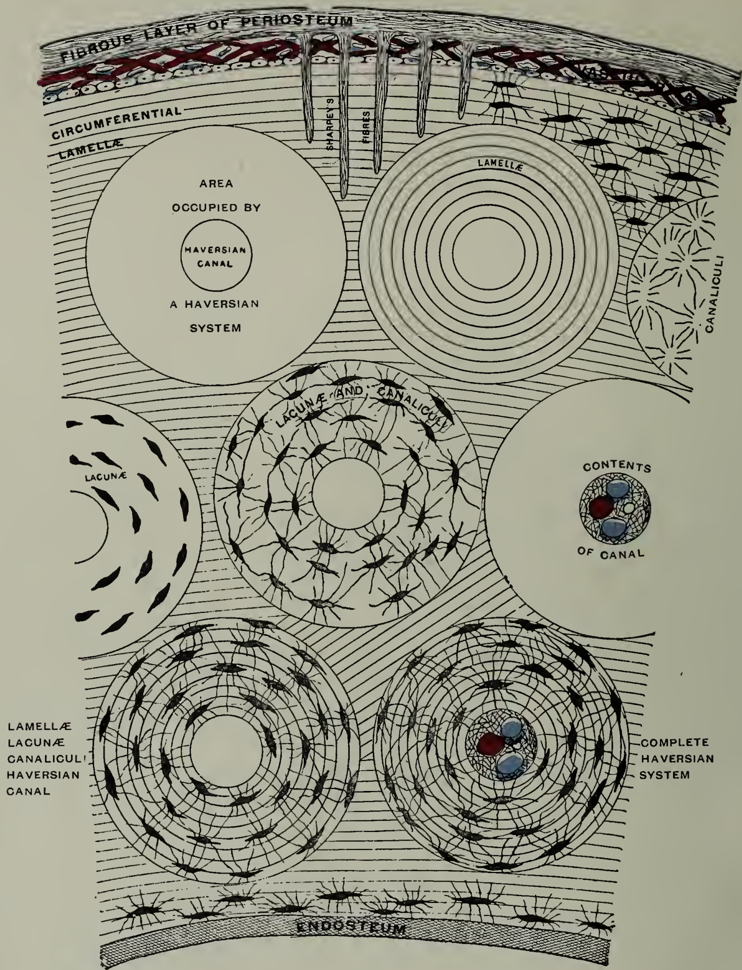


Fig. 13.—Diagram of the structure of osseous tissue. A small part of a transverse section of the shaft of a long bone is shown. At the uppermost part is the periosteum covering the outside of the bone; at the lowermost part is the endosteum lining the marrow cavity. Between these is the compact tissue, consisting largely of a series of Haversian systems, each being circular in outline and perforated by a central canal. In the first one is shown only the area occupied by a system; in the second is seen the concentric arrangement of the lamellæ; and in the others, respectively, canaliculi; lacunæ; lacunæ and canaliculi; the contents of the canal, artery, vein, lymphatic and areolar tissue; lamellæ, lacunæ and canaliculi; and, finally, all of the structures composing a complete system. Between the systems are circumferential and intermediate lamellæ, only a few of which are represented as lodging lacunæ, though it is to be understood that lacunæ are in all parts. The periosteum is seen to be made up of a fibrous layer and a vascular layer, and to have upon its attached surface a stratum of cells. From the fibrous layer project inward the rivet-like fibers of Sharpey. (Gerrish.)

is a complete system of little canals through which passes the nutritive materials.

The intercellular substance is in fibrous layers in which the mineral salts are deposited. These layers are called *lamellæ.* By reference to Fig. 13 the plan of the structure of bone may be seen in detail. The Haversian systems are seen in Fig. 14 under slight enlargement. The small dots seen on the sawed end of bone are the Haversian systems with the canals in the middle.

Fig. 14.—*A*, transverse section of a long bone, natural size; *B*, the dark part of *A*, magnified 20 diameters. Haversian systems of different sizes are seen, with canals, lamellæ and lacunæ. The enlargement is not sufficient to show canaliculi At *b* is a portion of the cancellated tissue. (Peaslee.)

In the shaft of a bone, one or more rather large holes are seen through which pass the nutrient artery. Other openings (*foramina*), which serve the same purpose, are seen near the expanded ends.

The *periosteum* is made up of two layers, the outer fibrous, and the inner consisting of a network of capillaries and osteogenetic cells. These latter are epithelial cells that secrete from the blood the materials that make bone. Growth and repair of bone take place by means of the periosteum, If any considerable portion of this is destroyed, the unprotected portion of bone dies. From the fibrous layer of the periosteum go prolongations into the bone that

are called "Sharpey's fibers." They attach the periosteum firmly to the bone.

The *endosteum,* or *medullary membrane,* is the nutrient layer on the inner surface of the shaft of long bones. It is a very delicate structure, consisting mostly of areolar tissue in which many capillaries are imbedded. They nourish the bone. About midway of the shaft, the nutrient artery enters the bone, sending its branches in all directions. The divisions finally terminate in the capillaries of the medullary membrane.

Dentinal Tissue.—This makes up the bulk of the tooth substance and is covered by a still harder material, the *enamel.* It is similar to bone, but instead of having the Haversian systems, there are radiating tubules that carry the nutritive materials.

EPITHELIAL TISSUE.

Distribution.—If we look at our own skin, we see a good example of this tissue, for while the skin contains other tissues, it is essentially an epithelium. The lining of the nose, mouth, eyelids, ears and the covering of the tongue are likewise epithelium. We find that every free surface of the body, including the internal organs is covered with this tissue. Every cavity is lined with it.

If the skin is broken or a part of it is brushed off as in a burn or blister, we realize what a *protection* this epithelial tissue is to the sensitive, underlying parts, besides preventing the escape of the fluids within. If we touch the lining of the mouth we realize how this tissue imparts smoothness to surfaces. This is true also of the lining of bloodvessels and cavities in the trunk and cranium.

Making secretions is exclusively the function of the epithelial tissue. The unit of structure, the epithelial cell, is like a little factory, using materials brought by the blood to manufacture something peculiar to itself. Among the various substances thus made, which have a definite place in the economy of the body, may be mentioned: saliva; bile; gastric juice; synovia; mucus; adrenalin; ear wax; cerebrospinal fluid; thyroidin, and many others.

When food has been transformed into such a state that it can become a part of the blood, the epithelial tissue attends to transferring it from the alimentary tract to the bloodvessels.

And, lastly, by this tissue certain sensory impressions, as those brought to the ear, are helped to be appreciated by the brain. These uses may be summarized, as epithelial tissue.

Lines and covers every free surface of the body.
Imparts smoothness to surfaces.
Prevents the escape of lymph.
Makes secretions.
Refines secretions.
Aids in the appreciation of certain sensory impressions.
Helps in the absorption of digested food products.

There are no bloodvessels in the tissue, but it is supplied by loops of capillaries coming up to the basement membrane. It is scantily supplied with nerves. This tissue after being destroyed is quickly replaced. The skin as an instance, heals in a short time after being broken.

The Epithelial Cell.—All this work mentioned above is done by cells of microscopical size and of varying shapes. The typical epithelial cell is spherical with a rather large nucleus, resting on a delicate connective tissue, *basement membrane.* The cells are held together by a very small amount of intercellular substance called "cement" substance. Spherical cells are not usually seen, as they require too much room. They are crowded together, with change of shape according to the direction of the pressure. If this is sideways, the cells become tall, like columns: *columnar, cylindrical,* or *conoidal.* If the pressure is from above, the cells are flattened, giving the names, *pavement,* or *squamous.* When the pressure comes from all sides, the cells become *polyhedral.*

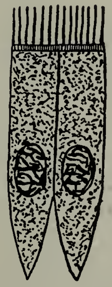


Fig. 15.—Two conoidal epithelial cells, their free ends furnished with cilia. (Gerrish.)

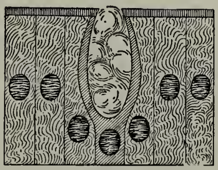


Fig. 16.—Goblet-cell, surrounded by cylindrical cells. (Gerrish.)

Some Specialized Cells.—*Ciliated* columnar cells have delicate processes projecting from their free surfaces, which move constantly, waving back and forth with a stronger motion in the direction toward the orifices of the body. They keep fluids moving and are numerous in the respiratory tract, and in a few other locations. By means of these cilia, mucus in the respiratory tract is moved along the bronchial tubes, and trachea until it reaches the point where the voluntary muscles can be used to expel it, as by coughing. (Fig. 15.)

Pigmented cells are irregular in shape and contain dark particles called *pigment.* They give the dark color to the skin and some other structures. In the skin this pigmentation protects the sensory nerves against the light. Blond peoples are more affected by strong sunlight, on account of the lack of pigment in their skin.

Goblet or *chalice cells* are specialized columnar cells found in mucous membranes. In these cells the nucleus is usually about the middle, but when activity begins it sinks to the bottom, the cells fill with granular material which swells, making them larger and crowding those nearby. Finally, the pressure within becomes so great, the cells break and their contents come out on the surface as *mucus*. (Fig. 16.)

Gland cells are of varying shapes according to the shape of the cavities to which they adapt themselves (Fig. 17).

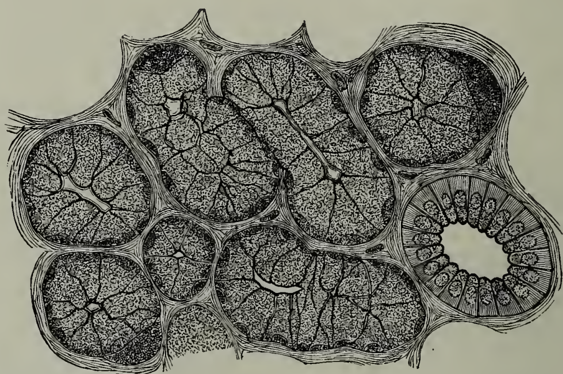


Fig. 17.—Glandular epithelium as seen in a salivary gland. At the lower right-hand corner is a duct lined with conoidal epithelial cells. (Kölliker.)

GLANDS.

Glands are masses of cells of various sizes and shapes whose function is the manufacture of special fluids from the blood. If the material manufactured is to be used again in the body, it is usual to call it a *secretion*, but if it is to be thrown off, it is called an *excretion*. The use of these terms is arbitrary and the best authorities tend to call both by the name *secretion*.

The elements concerned in the work of the glands are:

1. *Epithelial cells* which convert into their own structure materials brought by the blood, after which they produce some specific secretion.

2. The *lymph* which contains the materials for the nutrition of the cell and its product.

3. The *arterial capillaries* that permit the exudation of lymph from the blood.

4. *Secretory autonomic nerves* that determine the production or non-production of the specific substance.

5. The *vasomotor nerves* which permit the dilatation of the blood-vessels so increasing the supply of lymph, or constrict them, thus lessening the supply, after activity.

This secretion may be carried from the gland by a duct to some organ. To this the name of *external secretion* is applied. There may be no duct, and the secretion may be returned directly to the blood, as an *internal secretion.* Such glands are called *ductless glands.* The secretions are sometimes called "hormones," or "endocrines."

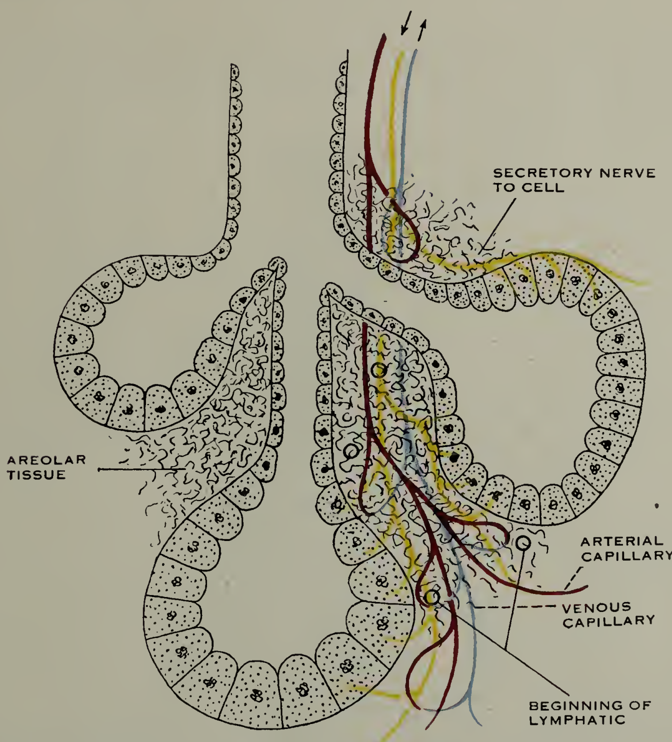


FIG. 18.—Diagram showing gland cells during rest. Also showing blood and nerve supply.

Varieties of Glands.—The simplest form of gland may be said to be represented by the goblet cell, which secretes mucus. It is on the surface, but all the glandular work of the body cannot be carried on at the surface, as there is not enough surface available, together with too much chance of interference and injury. The next most simple arrangement is a dipping down of the surface, so a group of epithelial cells may line a shallow tube. This would be called a "follicular" gland. The secretion is thrown out on the surface without any special duct. But, if the upper part becomes narrowed, and the cells covering it give up their secreting function, becoming simply a lining, a duct has been formed through which the secretion

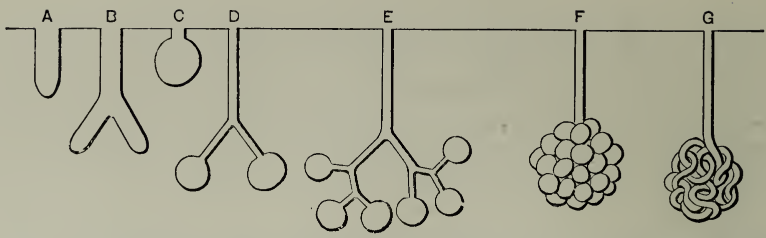


FIG. 19.—Diagram showing development of glands: *A*, a mere dimple in the surface; *B*, enlargement by division; *C*, enlargement by dilatation; *D*, a combination of *B* and *C*; *E*, a racemose gland; *F*, development of method of *E*; *G*, a single tube intricately coiled. (Gerrish.)

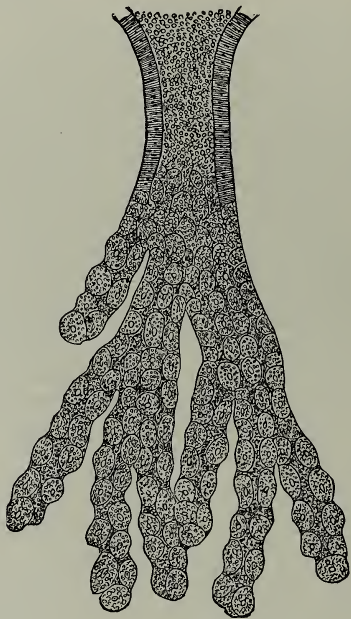


FIG. 20.—Compound tubular gland. The upper part is the duct; the lower is the secreting portion. (Kölliker.)

FIG. 21.—Compound racemose gland. The resemblance to a bunch of fruit is very marked. (Milne-Edwards.)

passes. See Fig. 22. The gland is tubular, and may be elaborated to any degree by branching.

If the dipping down becomes bulbous or globular by dilatation (Fig. 23), it is called "racemose," and this is a second type. It may increase by division, subdivision, and combination until it becomes a compound gland (Fig. 24).

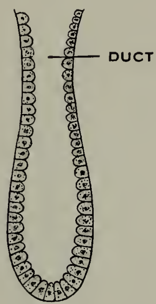


Fig. 22.—Simple tubular gland.

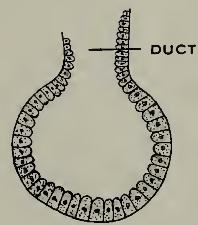


Fig. 23.—Simple racemose gland.

A fibrous network supports and gives shape to the divisions of compound tubular or racemose glands. In the network run the bloodvessels that supply the cells with nutriment and working

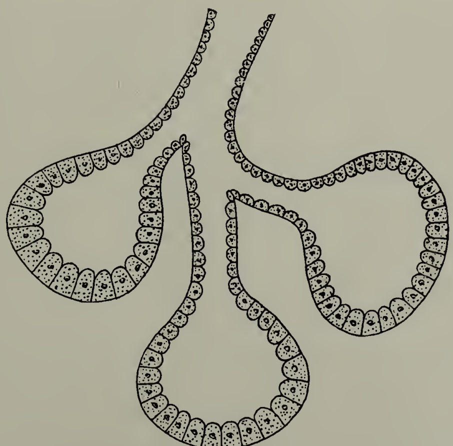


Fig. 24.—Compound racemose gland.

material, with the beginnings of the drainage tubes that carry off the waste or excess of material. The nerves that control the work of secretion are also found in this network. (Fig. 18.)

Glands have working periods and resting periods. During rest, there is an accumulation of granular material in the cells. After a

gland has been working for a time, the granular material has decreased or disappeared, apparently undergoing chemical changes in forming the secretion peculiar to that gland. An increased amount of blood is carried to a working gland, and, by the same control that increased it, the amount is lessened when the gland is resting.

There are two ways for the amount of activity and the quality of the secretion to vary. If the blood supply increases without additional stimulation of the cell by the secretory nerves, the secretion is more profuse but thinner. That is, it is of lower specific gravity. As an instance, when a sudden chilling of the surface of the body occurs, there is an accession of blood to the internal viscera, including the kidneys. More blood passing through these laboratories, there is an increased secretion of urine, having a lower specific gravity than before. If the secretory stimulus is increased, with correspondingly increased blood supply, the secretion is increased in amount without change in its character.

It should be remembered that the epithelial cells are microscopic in size, a small fraction of a millimeter in diameter and all the wonderful work that takes place in them is done by the aid of other microscopical structures.

MEMBRANES.

Membranes are sheets of tissue, covering, lining, connecting, separating, protecting, and secreting. Their structure may be mainly fibrous, epithelial, or a combination, in varying degree of the two tissues. Even the most delicate requires a slight basement membrane of fibrous tissue.

Fibrous membranes consist of layers of white fibrous tissue, intermixed with the yellow, elastic fibers. They vary in density, strength, and thickness. Examples, are the "dura mater," which covers the brain, and spinal cord, lines the cranium, and spinal canal, sending prolongations down between the various parts of the brain to separate them: the "interosseous membrane," which unites the two bones of the leg, and of the fore-arm, separating two groups of muscles; the "obturator membrane" that covers the obturator foramen; the "membrana tympani" that separates the external auditory canal from the middle ear; those membranes that cover organs, as the liver and kidneys, and the fascial membranes covering muscles.

Membranes that are composed mostly of epithelial tissue, consist of a single layer of flattened cells, held together by cement substance, and resting on areolar tissue which connects them to a thin fibrous layer. Such membranes do not communicate with the outside air, and are called "serous." They secrete a watery fluid

which serves as a lubricant. This class includes the "pleura" which lines the chest cavity, and covers the lungs; the "pericardium" which covers the heart, and forms a sac around it; the "peritoneum," which covers the abdominal viscera, and the "arachnoid" membrane, which covers the brain and spinal cord, lines the dura mater, and secretes the cerebrospinal fluid.

Of great delicacy of structure are the "medullary membranes," lining the medullary canal of long bones, and the "pia mater," a network of fine capillaries covering the brain and spinal cord. The basement membrane on which epithelial cells rest is very slight in texture.

Similar to these serous membranes in structure, and not communicating with the outside air, are "synovial membranes." These line the interior of joint structures, making smooth the inside surface of ligaments. They secrete a glairy, colorless fluid, called "synovia," which is similar in appearance to the white of egg. This fluid is essential for the lubrication, and frictionless working of joints. This same membrane lines the little fibrous tissue sacs, called "bursæ" which are placed between parts that move on each other, as a muscle over a rough bone, one muscle over another, or the skin over a bone. Another use is in lining the bony grooves in which tendons run. These structures are known as "vaginal synovial membranes," or "synovial sheaths."

A very common membrane is that known as "mucous." It lines surfaces that *do* communicate with the outside air, such as the nose, eyelids, mouth, trachea, bronchial tubes, esophagus, stomach, intestines, etc. Mucous membranes are much thicker than are those of the serous group. They have several layers of cells, of which the uppermost is columnar, often ciliated columnar. These layers of cells rest on an extensive network of fibers in which numerous bloodvessels and nerves ramify. In the Schneiderian membrane lining the nose, the plentiful blood supply enables the membrane to warm and moisten the inspired air.

The secretion of this membrane is "mucus," which may be thin in consistency, of a mucilaginous nature, but is often quite thick, even stringy. Congestion, or increased blood supply increases the amount of this secretion. In the progress of a catarrhal cold, the mucus varies from a watery to a consistency that is almost a solid.

Mucous membranes are frequently associated with the simpler forms of glands, as in the walls of the stomach, and the small intestine.

Combinations of fibrous and epithelial membranes have a firm, fibrous base, with the epithelial cells at the surface. There may be but one layer of the latter. Examples of these are the eardrum, the epithelial layer of which secretes wax; the periosteum of bone, and the perichondrium of cartilage.

4

Lastly, is the "cutaneous" membrane, known as the skin. This is a combination of many structures, described in a later section. In connection with their associated structures, many of the above membranes are described in detail.

MUSCLE TISSUE.

This is the tissue in which contractility is especially developed. It is found in three forms:

1. *Striated,* or cross-striped.
2. *Smooth,* or plain or non-striated.
3. *Cardiac.*

Striated Muscle.—Striated muscle is that form of the tissue which is attached to the bony skeleton, is under the control of the will and has to do with such manifestations as are peculiar to animals, *i. e.,* as motion.

It makes a large portion of the bulk of the body and is identical with what is known in the lower animals as lean meat. The specimen from the butcher, before referred to, should be examined to see its physical properties.

In color it varies from a deep red to a pale pink, according to the amount of blood contained and the size of the fibers. It is somewhat elastic, is easily torn and is attached to the bones by means of tendons or directly through the periosteum. A coat of fibrous tissue covers every appreciable amount of it, and even its unit of structure, the fiber, is covered with fibrous material.

The Muscle Fiber.—The fiber is the unit of muscle tissue. It is cylindrical in shape, with rounded ends. On the outside is a delicate fibrous sheath, the *sarcolemma.*

If the fiber is placed under a microscope of moderate power, it appears to have cross-way stripes or striations. These give the name to this class of muscle tissue. Besides the cross stripes there are very delicate lines longitudinally. Under a high-power microscope, the fiber appears to be made up of a number of parallel fibrils, having long spindle-shaped processes alternating with round bead-like ones, with constrictions between them. These fibrils are the contractile portions of the fiber. When they contract, the spindles and beads shorten longitudinally and broaden transversely. Between the fibrils is a liquid material, the *sarcoplasm,* which is pushed aside by the change in the contractile elements, so the muscle fiber shortens and broadens in contraction.

The Tendons of Muscles.—The tendon is made up from the aggregation of the coverings extended beyond the fiber.

There are various ways in which the fibers are placed in regard to the tendon. Sometimes the bundles of fibers are parallel and spindle-shaped, with tendons at each end: the fusiform arrange-

ment. Or, the tendon may be at one side with the fibers placed at an oblique angle with it. This is the "penniform" arrangement. There may be fibers on both sides of the tendon, the "bipenniform"

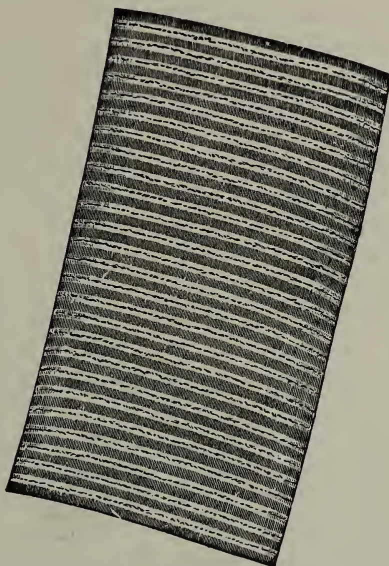


FIG. 25.—Part of a fiber of cross-striped muscular tissue, showing the alternating bands. (Gerrish.)

FIG. 26.—Diagram showing the minute structure of cross-striped muscular tissue. (Gerrish.)

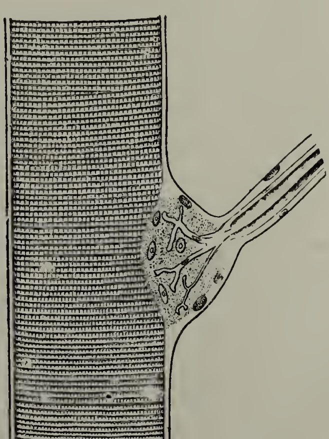


FIG. 27.—Motorial end-plate, the termination of a nerve in a fiber of cross-striped muscle. (Testut.)

arrangement. These arrangements vary according to the work to be done. The tendon, instead of being cord-like may form a sheet that covers much of the muscle, as an "aponeurosis." Or, there may be several rows of muscle fibers with lines of tendon crossing them, forming a "tendinous inscription."

Arrangement of Muscle Fibers.—Fibers vary in length from $\frac{1}{5}$ inch to 2 inches. In width they vary from $\frac{1}{2500}$ of an inch to $\frac{1}{250}$ of an inch. If the muscle is more than 2 inches long, the fibers are joined end-to-end to make up the necessary length. In a fiber many fibrils are bundled together, the fibers are grouped in a bundle, and this bundle with other bundles, until the bundles of bundles become a real muscle as seen in the body by the naked eye. Each successive group has its own fibrous investment.

Between the fibers is areolar tissue in which run the bloodvessels, as well as the lymphatics and the nerves. (Fig. 29.)

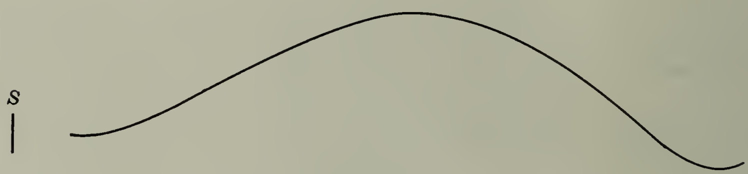


FIG. 28.—Curve of simple muscular contraction.

If a proper apparatus is arranged, so the contractions may be shown on a paper placed on a revolving drum, some such figure as in Fig. 28 would result. It would show that the muscle does not contract the instant the stimulus is applied, but that there is a time of preparation, after which the contraction occurs, reaches a maximum intensity, and then declines from this maximum to the end of the contraction. This time of preparation is called the "latent" period. In Fig. 28 the time at which the stimulus is applied is indicated by "S."

The Muscle and its Nerve.—An essential part of the muscle cell or fiber is the motor nerve ending. Every cell has its motor nerve by which it is stimulated to contract. So intimate is this arrangement that it is fair to speak of a muscle fiber as a muscle and nerve combined. (Foster.)

The muscle contracts after it is stimulated by the nerve, and then it rests until another stimulation occurs. Each contraction may be compared to an explosion which follows the stimulus. The more frequent the stimuli, the more frequent the contractions.

Plain or Non-striated Muscle Tissue.—This is the form of muscle which is not under the control of the will, but is stimulated through the autonomic nervous system. It is found in the walls of blood-

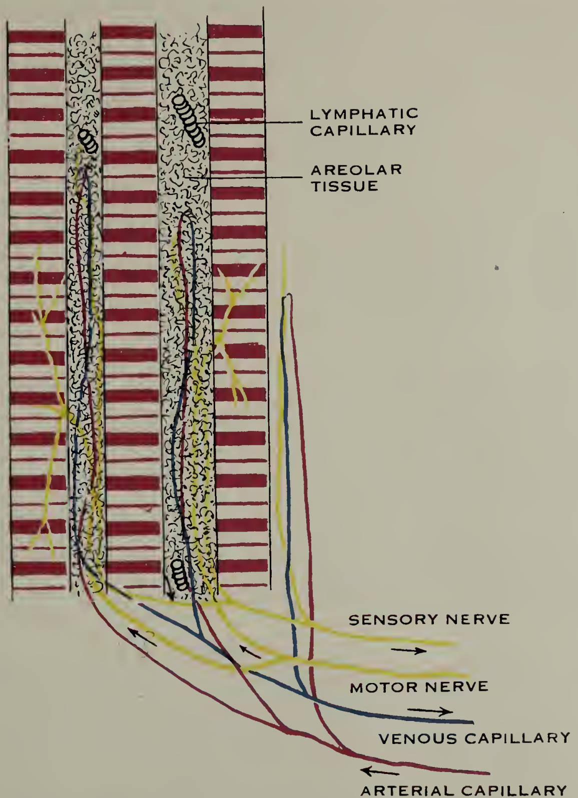


FIG. 29.—Diagram of muscle tissue with arrangement of bloodvessels and nerves.

FIG. 30.—Cells of plain muscular tissue. (Gerrish.)

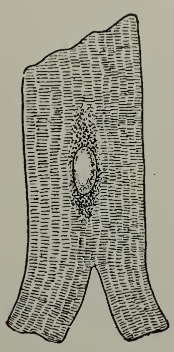


FIG. 31.—Cell of cardiac muscular tissue. (Testut.)

vessels, and hollow viscera, aiding in the performance of those functions that are called "vegetative."

The microscopic unit is the cell or fiber, which is fusiform in shape. About the middle of it is some granular material and quite a large nucleus. The size varies from $\frac{1}{500}$ to $\frac{1}{10}$ of an inch in length, with the width a fraction of these.

A delicate sheath covers each cell, with areolar tissue surrounding it. The color is pale, and their blood supply less profuse than is that of the voluntary muscles.

These fibers are not arranged in bundles but in sheets. The fibers run around the vessel or lengthways of it. They may go in all directions in the hollow viscera.

The contraction of this tissue occurs in a long-continued rhythmic wave. This can be well seen in a freshly killed animal if a stimulus (blow) is given to the coil of intestines. In the digestive organs this rhythmic wave is called *peristalsis*. A marked difference between striped and unstriped muscle fibers exists as to their contraction. In the striped variety energy is expended in producing a contraction; in the unstriated an initial shortening is continued as a *pull*. Thus the contraction is held after the first effort. The striated muscle must make a succession of efforts.

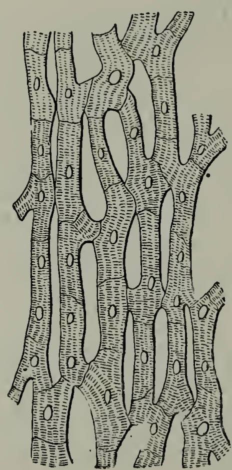


Fig. 32.—Cardiac muscular tissue, the cells united in a network. (Testut.)

Cardiac Muscle Tissue.—This is a form found only in the heart. In appearance it has some of the characteristics of both the striated and non-striated muscle. It presents irregular cross-striations. The cells are short and branched, with large nuclei. They are arranged in a network, by being joined end-to-end, which leaves many open spaces. The blood supply is very ample. The contrac-

tions are rhythmic, with waves passing in a circular fashion around the cavities of the heart. These contractions are followed by periods of rest. It is not under the control of the will, though it is affected much by the emotions.

NERVOUS TISSUE.

This is the highest grade tissue in the body, the master tissue, which if injured or destroyed is most difficult to replace. It is found all over the body, with aggregations in the brain, the spinal cord and in the trunk in front of the spinal column. It is divided into gray and white nervous tissue.

Gray Nerve Tissue.—The gray matter is pinkish-gray in color, found on the outer surface of the brain, the center of the spinal cord, and in the masses in the trunk. It is the active part of the tissue, receiving impressions, sending orders, coördinating, considering, remembering and originating impulses. It consists of cells.

White Nerve Tissue.—The white matter consists of fibers of gray matter covered by a white coating which protects it. These fibers simply carry messages to and from the centers, but do not originate any.

The Neuron.—The unit of nerve tissue is the *neuron*. This is a granular, pigmented, branched and nucleated cell. The body of the cell is called the *cyton*. It is reddish in color, with occasional darker patches. In the protoplasm are peculiar granules, known as *Nissl's granules*. They go as far as the dendrites, but not into the axone. During fatigue or after prolonged stimulation of the axone, they disappear. They are said to represent a certain amount of nervous energy. In some mental diseases they are absent.

The nucleus of the cell is large and contains a nucleolus. The cell always has at least one long process called the *axone* or axis-cylinder process. This axone is prolonged as a fiber, going to some part of the periphery. The branching processes of the cells are called *poles*. These divide and subdivide into protoplasmic processes called *dendrites*. The axone may remain without coating as a gray nerve fiber, or it may become invested with the white coating and become a white nerve fiber. This covering is soft and oily, known as the medullary sheath or " white substance of Schwann." It is surrounded by a fibrous sheath, the *neurilemma*. Situated here and there in the "white substance of Schwann" under the neurilemma, are nuclei. The medullary sheath covers the fiber except at intervals where only the neurilemma invests it. These intervals are called the "nodes of Ranvier." At its termination, the axone divides into a number of branches from which the coating is absent. (Fig. 33.)

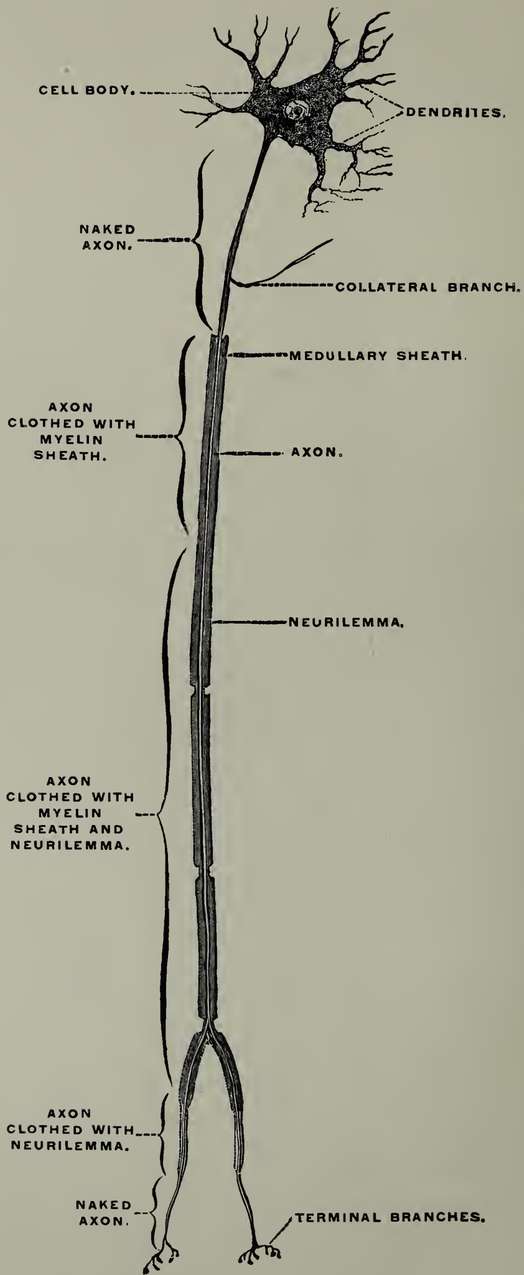


FIG. 33.—A neuron. (Stöhr.)

The Nutrition of the Nerve.—The nutrition of the nerve fiber is through its cell. When the fibers are separated from their cells, degeneration, either upward or downward ensues. A similar degeneration occurs in muscles when they are separated from their nerve supply. The "reaction of degeneration" is determined by the varying response to the stimulation of different electrical currents.

Nerves.—Nerves as seen in the body look like white cords, of varying size. They consist of a bundle of fibers, held together by areolar tissue, in the meshes of which run the bloodvessels and lesser nerves which nourish them.

Nerve fibers carry messages in two directions, either from or to the center. Those that carry from the center are called "efferent" and grow from the center outward, as the motor nerves.

Those which carry to the center (afferent nerves) grow inward from the nerve cells in organs of special sense or the tactile corpuscles (touch), etc., and their fibers branch within the nerve centers and communicate with the cells. Afferent or sensory nerves pass between the muscle cells to sensory centers.

THE LIQUID TISSUE.

Physical Characteristics.—This is known as the *blood,* a red, opaque fluid, somewhat viscid, having a peculiar stale odor, a salty taste, and of an average specific gravity of 1055. This varies according to the amount of water ingested.

The temperature of the blood averages 98.6° F., or 37° C., with a higher temperature in the deeper vessels, and even 107° F. in the vessels of the liver.

The weight of the blood is estimated as one-eleventh that of the body.

The reaction of the blood is slightly alkaline. This is essential to the life of the cells, as they cannot function in acid surroundings. Faulty action of the liver and kidneys, as well as errors in diet, may cause an acid condition of the blood.

About one-half the bulk of the blood is a fluid, the *plasma,* in which float innumerable minute solid bodies, called cells or corpuscles—red or white.

The Plasma.—The plasma is clear and transparent, of a very light yellow tinge.

While the blood is in a system of closed tubes its liquid part is plasma. When this has oozed through the walls of the capillaries into the spaces surrounding them, the fluid is called *tissue fluid.* It receives the waste from the cells, so differs from plasma. When it gets into the lymph capillaries, it is called *lymph.* (The terms "perivascular," "intercellular" and "lymph spaces" refer to these same spaces, but as they relate respectively to the capillaries, the

cells and the lymphatic vessels.) A specimen of the tissue fluid may be seen in the watery fluid that exudes when the skin is broken over a blister.

Plasma has a specific gravity of 1026 to 1029. It is 90 per cent water in which are dissolved various proteins, sugar, fat, amino-acids, inorganic salts, waste materials, including urea, new food materials, etc., in addition to oxygen, nitrogen and carbon dioxide. The 10 per cent solids consist of:

Proteins	8.200
Amino-acids	0.005
Fats	0.250
Sugar	0.100
Broken-down material	0.600
Inorganic salts of sodium Potassium, calcium and magnesium	0.850

The percentage of amino-acids in the plasma is much increased soon after a meal, especially if much protein food has been taken. Apparently, part of these amino-acids are built up into the tissue cell during the intervals between meals. A part may be transformed in the liver into urea.

Soon after a meal the percentage of sugar and fat also are increased.

The products of katabolic activity that enter the plasma includes urea, uric acid, creatinin, ammonia and other nitrogenous compounds. These materials are being produced and removed during life, so the percentage remains fairly constant.

Plasma may be considered as representing the intercellular material between the cells or corpuscles. There is about an even division as to bulk.

The Serum.—If a quantity of blood is drawn from the body, and allowed to stand in a glass tube, there is, presently, a division into a solid dark-red mass at the bottom, and a clear, light-yellow fluid above. This fluid is *serum*, and the use of the term always means it is outside the bloodvessels, as well as outside the lymph spaces. It is distinguished from plasma by the lack of fibrinogen, an antecedent of fibrin. The solid mass is *clot* or *coagulum*, made up of corpuscles or cells caught in a network of fibrin. Plasma itself, when removed from the bloodvessels, will coagulate, forming a soft clot of fibrin and the clear serum. Apparently, the corpuscles are not needed to induce clotting, but some elements in the plasma are always concerned (page 57).

Corpuscles, or Cells.—These are in three classes:

1. *Red corpuscles* (*erythrocytes*), numbering 4,500,000 to 5,000,000 per cubic millimeter.

2. *White corpuscles* (*leukocytes* or *lymphocytes*), from 7000 to 10,000 per cubic millimeter.

3. *Blood platelets* (*thrombocytes*), about 200,000 per cubic millimeter.

A fourth element is the *blood dust* or hematokonia, of which very little is known. It appears as minute refractive granules, and may be the fragments of broken-down red corpuscles.

The Red Corpuscles.—Red corpuscles are minute bodies visible under a low-power microscope. Singly, they have a pale yellow color, but in mass are red.

Examination on a slide shows them as biconcave, circular disks, which have a way of rolling up like a pile of coins. When fresh blood, mixed with a normal saline solution (0.06 per cent) is examined, or the circulating blood is studied, the corpuscles are seen to be bell-shaped. Their greatest diameter is 0.007 mm., or they are of a size to go single file through the smallest capillaries.

The red cells have no nucleus. It is claimed that there is a surrounding colorless membrane, in which is a semi-fluid mass, consisting of protein, lecithin, cholesterin, hemoglobin and various organic salts. The water in the red cells is 65 per cent, leaving 35 per cent of solids. Of this part, 94 per cent consists of hemoglobin.

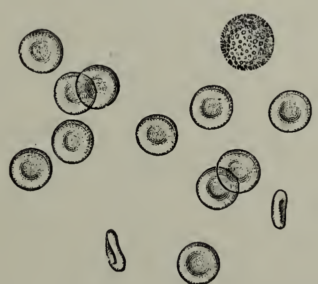


Fig. 34.—Blood corpuscles. One colorless corpuscle is seen at the top; the others are colored. (Dalton.)

Red corpuscles are daily destroyed in large numbers and new ones made. It is supposed the destruction takes place mainly in the spleen and the liver. New corpuscles seem to be made in the red marrow of the bones. Large nucleated cells called *erythroblasts* develop from marrow cells. They divide and multiply, becoming known as *normoblasts*. At first they have nuclei, but these lessen in size and are finally thrown off. The rest of the body goes out as a red corpuscle.

This theory of the formation of erythrocytes is strengthened by the fact that after a severe hemorrhage the process of new cell production is so rapid, some of the erythroblasts and normoblasts get out into the blood stream before they have thrown off their nuclei. The red corpuscles are supposed to be completely renewed every

sixty days. This is of interest as influencing the length of time needed to see results in treatment of the sick.

In various animals the red cells differ in size and shape, according to the need for respiration, but microscopically those of mammals are virtually the same as those of man.

The Hemoglobin.—Hemoglobin is very complex, consisting of carbon, oxygen, hydrogen, nitrogen, sulphur and iron. Iron equals $0.33\frac{1}{3}$ to 0.5 per cent of the whole. Estimates place the total amount of iron in the body as 2.9 gm. While this amount is very little, its presence in hemoglobin enables the red corpuscles to combine with and carry oxygen from the air in the lungs to the ultimate tissue cells. After this there is a release of alkaline material from the hemoglobin, which combines with the CO_2 waste from the tissues, producing bicarbonates of soda and potash, in which form the waste is carried to the lungs.

White Corpuscles.—The white cells are colorless, but in the mass are white. They are spherical, larger than the red cells, contain a variable number of nuclei, and by virtue of their power of "amœboid movement," can get out of the bloodvessels into the perivascular spaces. Their name of "wandering cell" refers to this peculiarity. "Amœboid movement" is the throwing out of a slender process, and then moving the rest of the cell after it.

By their reaction to staining agents, white cells are divided into two groups:

The first group, comprising 25 to 30 per cent of the whole number, are *lymphocytes, small* or *large*. These develop in the lymph glands, solitary follicles, etc. They are washed out of the glands by the lymph, and so enter the blood stream. They seem to be mainly useful in limiting the spread of infections by blocking the lymph spaces, or "walling off" the infected areas.

The second group developing from the *myelocytes* in the red marrow, comprise "polymorphonuclear" leukocytes (60 to 70 per cent of all white cells), the *eosinophiles* and the *basophile* cells. This group is supposed to remove broken-down tissue and invading bacteria. By their amœboid movement they go out into the tissue spaces, surround and take in these substances—digesting them. This process is called "phagocytosis," and the cells are called *phagocytes*. This work is helped by the development in the tissues of a material which gets into the plasma. This is "opsonin," and its quantity probably measures the resistance of the organism to infection. Inflammation with pus formation (another protective agency) increases the number of leukocytes. The débris of the broken-down tissue, plus the dead phagocytes equals *pus*.

Leukocytes may also absorb fat from lymphoid tissues in the intestine. They presently die and add protein to the plasma, which *may* help in the coagulation of the blood.

Platelets.—These are very minute corpuscles without nuclei, but with a central granular and clear bordering structure. They are about 2 microns in diameter, and seem to be disk-shaped—possibly biconcave.

With fibrin· they form most of the thrombi that develop in diseased bloodvessels. Their function is unknown, but it may be to help in the coagulation of the blood. When their number in the blood is much decreased, coagulation occurs very slowly.

Blood as a Carrier.—As the nutritive materials, wastes, internal secretions, etc., are in the plasma, while the red cells are loaded with oxygen, the blood may be considered as a common carrier, taking:

The products of digestion to the tissues.

The waste products from the tissues.

The oxygen taken in by the lungs to the tissues.

The carbon dioxide waste from the tissues to the lungs.

The internal secretions from the ductless glands to the tissues; *and* it is also instrumental in regulating the heat of the body.

Functions of the Liquid Tissue as Related to Cells.—The lymph surrounds the various tissue cells, constantly bathing them. According to the hydraulic pressure within the cells or in the lymph, the cells take up their needed elements from the lymph or exude the waste material. It is supposed that the metabolism of a part of the protein and of all the carbohydrate and fat occurs in the lymph spaces. Only a part of the protein is built up into the cell structure.

Nutritive and waste materials are both present all the time. The means by which the lymph enters and leaves the lymph spaces will be discussed in the Chapter on the Circulatory System.

QUESTIONS.

Name the commonest forms of fibrous tissue.

What are the characteristics of white fibrous tissue that make it useful as ligaments and tendons?

Name the uses of cartilage. Where is it found as a temporary structure?

Describe the structure of "recent bone," and tell the uses of its parts.

Where is epithelial tissue found? What are its uses?

What are glands?

Why is striated muscle tissue connected with bones instead of being in the walls of the stomach?

Describe a neuron.

Describe blood, as to its physical properties. Of what use is it?

What is lymph? What relation has it to serum?

Examine the leg of a chicken and identify all the tissues.

CHAPTER III.

THE OSSEOUS SYSTEM.

Distribution of Bone.—Bones form the framework or skeleton of the body, to which the muscles which move different parts are attached; they serve as levers; they support and protect soft parts which are concerned in the more vital functions, as the brain, thoracic, abdominal and pelvic viscera.

Classes of Bones.—Usually the bones that form cavities are broad and flat, while those that have to do with the leverage of muscles are elongated. As structure varies according to use, there are three different classes of bones, flat, irregular and long. Flat bones have outer layers or "tables" of compact bone, with an inner filling of spongy bone.

The *irregular* bones are similarly covered with compact bone with spongy bone within, and are of such varied and irregular shapes they cannot be classified as either flat or long.

Long bones, regardless of absolute length, have hollow cylindrical shafts of compact bone, with expanded ends of cancellous bone, covered by a thin shell of compact bone. The expanded ends provide increased surfaces for joints, while the hollow shafts ensure sufficient strength with little weight, and provide space for certain nutritive elements, as the marrow and bloodvessels.

Development of Bones.—In the embryo, bones are preformed in either cartilage covered with membrane or in membrane alone. As development proceeds, bone salts are laid down under the membrane in spots called "centers of ossification." In long bones, these centers are in the shaft and extremities. As the process proceeds the main shaft, called the diaphysis, becomes entirely ossified and the extremities, or epiphyses, likewise. Until the time arrives when growth is completed, a layer of cartilage, the epiphyseal cartilage, remains between them. When this also is ossified, the bone has become "mature." All bones do not reach maturity at the same time. Usually between the ages of sixteen and twenty-two years the various bones complete their growth, though occasionally maturity is delayed until the twenty-fifth year (Fig. 12).

Long bones increase in length by additions at the ends, on each side of the epiphyseal cartilages, but the increase in girth or diameter occurs by the laying down of bone-salts under the periosteum.

Flat bones increase in size by additions at their edges, as in the bones of the skull.

According to the age and the muscular development of the individual the surface of bones varies much. As the muscular use

increases, the bones show more distinct roughness. (In selecting bones for study pick out those that show the various markings most distinctly.)

Markings on Bones.—The markings on bones may be either elevations or depressions. The elevations include, *tubercle,* a blunt prominence smaller than a *tuberosity; spine,* which is a sharp prominence; *process* which may be an outgrowth of any shape or size; *ridge, crest* or *line* when narrow; *condyle* if broad and articular, and *head* if supported on a neck. Depressions of bone include *fossa* and *cavity,* which are more or less shallow; *foramen,* a hole; *fissure,* a narrow slit; *canal,* a long tube-like passage way.

Muscular Attachments on Bones.—The muscular attachments to bone are denominated origin and insertion, considering origin the fixed point and insertion the movable point, but as in action these are frequently reversed, it is more satisfactory to consider *origin* as referring to the attachment nearer the center line of the body or the upper part of an extremity, and *insertion* that more distant from these points. No description fits all specimens as no two bones are exactly alike either in size, shape or markings.

THE BONES OF THE SKELETON.

The skeleton in the adult consists of 206 bones (including the small bones of the ear) grouped as follows:

The bones of the head (22).

8 cranial bones	1 frontal 2 parietal 2 temporal 1 occipital 1 ethmoid 1 sphenoid
14 facial bones	2 malar 2 lachrymal 2 nasal 2 superior maxillary 2 palate 2 turbinate 1 inferior maxillary 1 vomer

The bones of the trunk (52).

24 vertebræ.
1 sacrum.
1 coccyx (sometimes four or five sections).
24 ribs.
1 sternum.
1 hyoid.

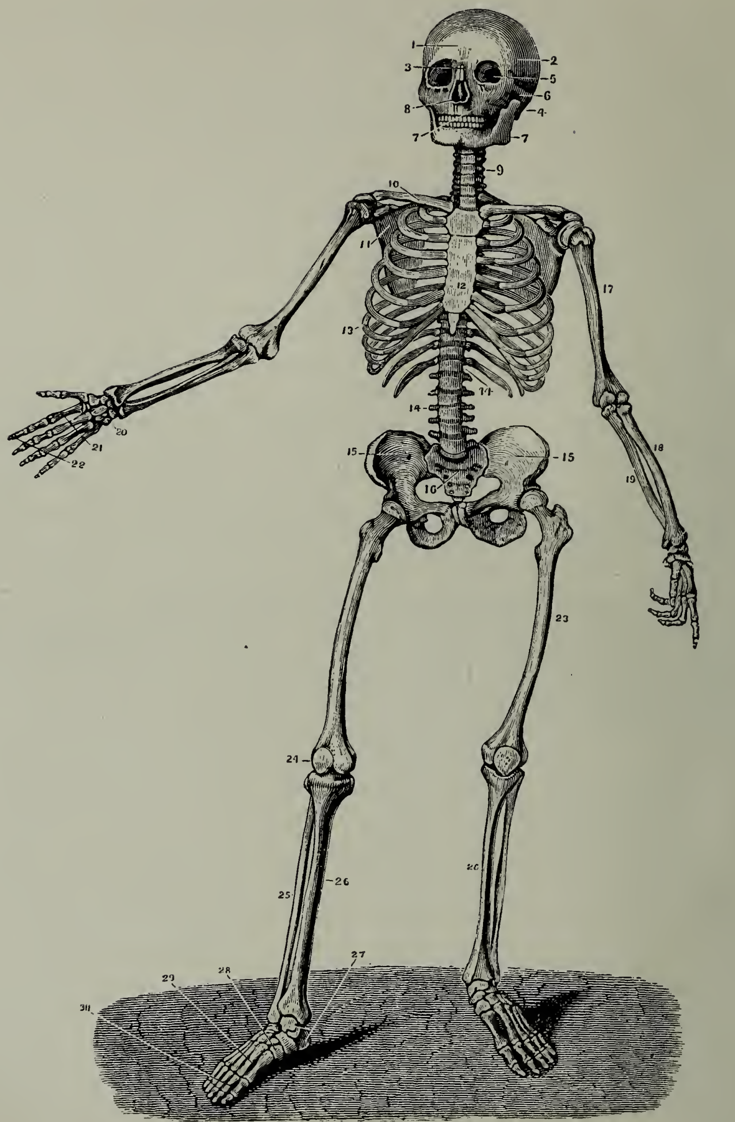


FIG. 35.—Front view of adult skeleton.

1. Frontal bone
2. Parietal bone
3. Nasal bones
4. Occipital bone
5. Orbits of eyes
6. Malar bone
7. Upper and lower maxilla
8. Nasal cavity
9. Cervical vertebræ
10. Clavicle
11. Scapula
12. Sternum
13. Ribs
14. Dorsal and lumbar vertebræ
15. Innominata
16. Sacrum
17. Humerus
18. Radius
19. Ulna
20. Carpus
21. Metacarpus
22. Phalanges
23. Femur
24. Patella
25. Fibula
26. Tibia
27. Calcis and astragalus
28. Cuneiform and cuboid
29. Metatarsus
30. Phalanges of toes.

The bones of the upper extremity (64) or 32 on each side.

1 scapula, or shoulder blade.
1 clavicle or collar bone.
1 humerus or arm.
1 radius } forearm.
1 ulna }
8 carpal or wrist bones.
5 metacarpal or palm bones.
14 phalanges or finger bones.

The bones of the lower extremity (62) or 31 on each side.

1 os innominatum or hip bone.
1 femur or thigh bone.
1 tibia } leg.
1 fibula }
1 patella or knee-cap.
7 tarsal.
5 metatarsal.
14 phalanges or toes.

The sternum is sometimes said to form several bones, hence the varied numbers of the bones in the skeleton given in different books.

THE BONES OF THE SKULL.

The Bones of the Cranium.—The eight bones of the cranium are so placed as to form a hollow, somewhat spherical receptacle for the brain. They are joined to each other by sutures.

Frontal Bone.—Forming the greater part of the forehead is the frontal bone. The internal surface lodges the anterior lobes of the brain, or that portion said to contain the intellectual centers. On the lower, external aspect, the eyebrows are placed above the orbital cavity. The frontal bone helps to form the socket in which the eyeball is placed. Its overhang is a great protection to the eye.

Parietal Bone.—Back of this are two quadrilateral bones called the parietals, which are united by a suture in the middle of the skull called the parietal or sagittal suture.

Temporal Bone.—Two temporal bones situated at the sides and base of the cranium, are described as having three distinct portions, the squamous, the petrous and the mastoid process. The petrous portion contains the internal ear and the canal leading thereto, and supports the cartilaginous external ear or auricle.

To the mastoid process are attached the sternomastoideus, the splenius capitis and the trachelomastoideus muscles. The squamous portion gives attachment to several muscles concerned in mastication

Occipital Bone.—The posterior-inferior part of the cranium is formed by the occipital bone. On this are several points of interest.

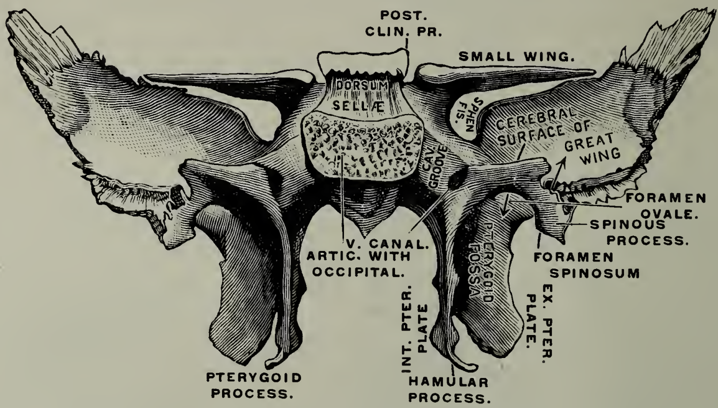


FIG. 36.—The sphenoid bone, viewed from behind. (Testut.)

FIG. 37.—Skull, viewed from the left side, showing the principal cranio-metric points. (Gerrish.)

A large foramen (*foramen magnum*) gives passage to the spinal cord as it passes from the brain into the spinal canal. Anteriorly to the foramen are two articular processes where the skull rests upon

the atlas, articulating with it. The posterior surface presents a prominent process of bone called the *external occipital protuberance* to which the ligamentum nuchæ is attached. Curving outward from this on each side are the superior curved lines to which are attached the occipito-frontalis, the trapezius, and splenius capitis

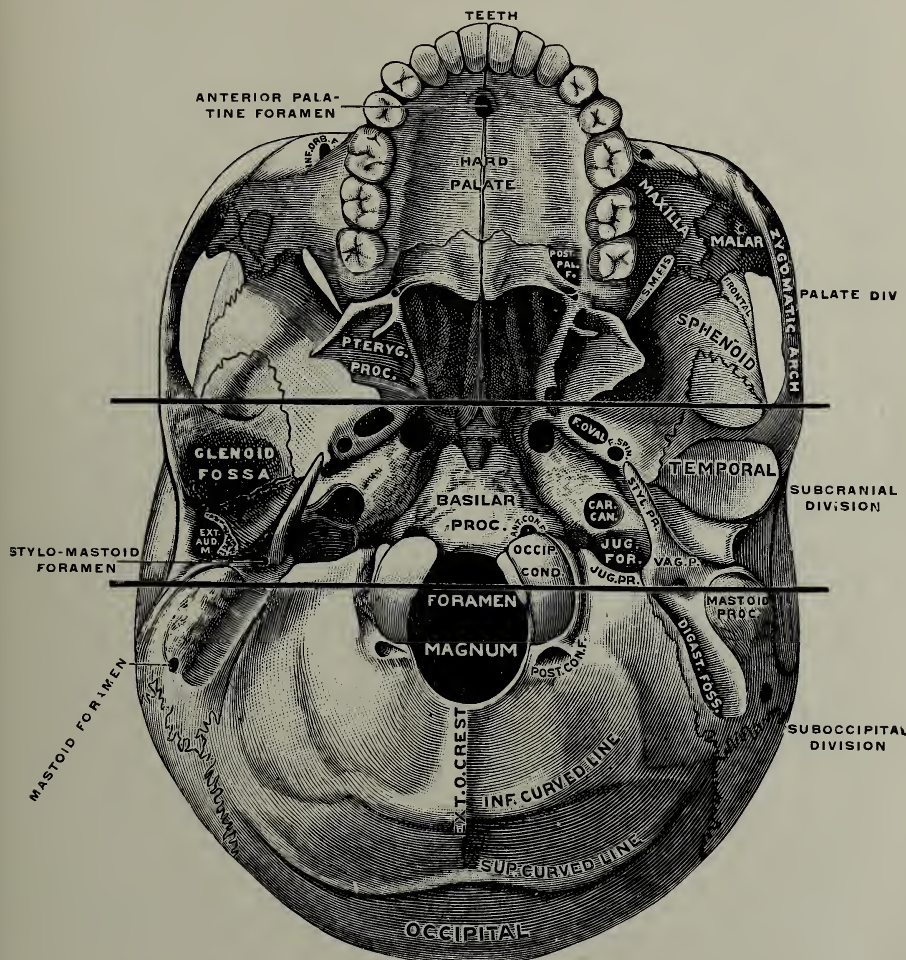


Fig. 38.—Base of the skull, viewed from below, the mandible having been removed. (Testut.)

muscles. Below the superior are the inferior curved lines, and to the space between are attached the complexus, the rectus capitis posticus major and minor, and the obliquus superior muscles.

Sphenoid Bone.—The sphenoid, a bat-shaped bone, is wedged in between the bones at the base of the skull. It articulates with all

the other cranial bones. A depression, on the upper surface of the body, called the *sella turcica,* lodges the ductless gland, called the *pituitary body.*

Ethmoid Bone.—The ethmoid is a small bone that helps to form the nasal and orbital fossæ.

Sinuses.—On the interior of several of the cranial bones are grooves or sinuses in which are large veins to drain the blood from the brain. Several of these meet just at the side of the occipital protuberance, forming what is known as the *torcular herophili,* or the "wine-press of Herophilus," as extensive hemorrhage occurs here in fracture of the skull.

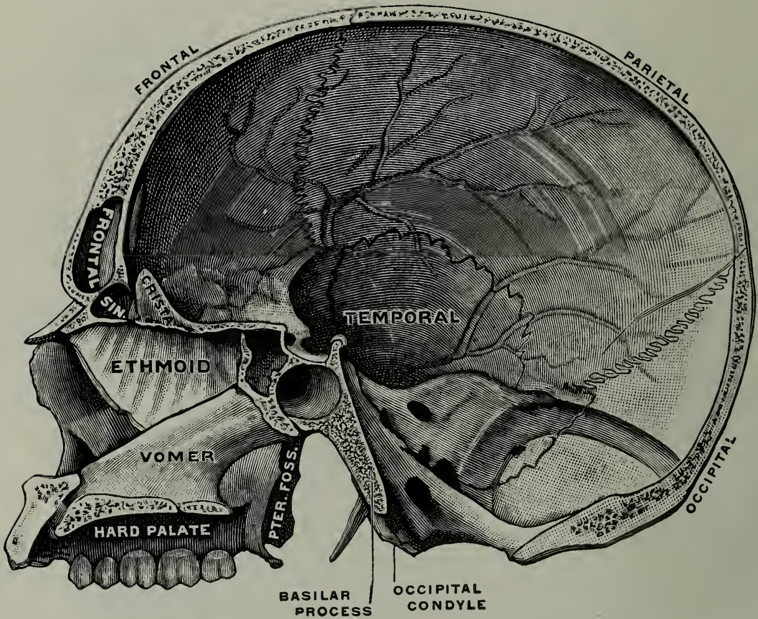


FIG. 39.—Sagittal section of skull, a little to the left of the middle line, the inner surface of the right half. (Testut.)

The term *sinus* is also used to indicate fairly large spaces in the frontal, sphenoid, ethmoid, and superior maxilla bones. These spaces contain air, and are lined with mucous membrane that is continuous with that lining the nose. They communicate with the nasal passages.

The venous sinuses are *within* the cranial cavity, while those spaces in the bones are outside of it.

The Bones of the Face.—The fourteen bones of the face form the framework to which the muscles of expression are attached as well as some that have to do with mastication and deglutition. They

form part of the nose, as well as of the orbital, and oral cavities. The sockets in which the teeth are set are in the two maxillary bones.

The two *malar* bones form the prominence of the cheek; the *lachrymal* bones help form the canal for the tear duct; the *nasal* bones form the upper part of the nose; the *inferior maxillary* or *mandible* is the lower jaw in which are the alveolar processes for the teeth, and to which numerous muscles are attached. The two *superior maxillary* and two *palate* bones form the roof of the mouth, the former providing sockets for the upper teeth. The two *turbinated* bones provide the base for a large surface of nasal mucous membrane, while the *vomer* forms the lower and back part of the septum between the two sides of the nose. (Figs. 37, 38, and 39.)

THE BONES OF THE TRUNK.

The Thoracic and Abdominal Cavities.—The bones of the trunk are arranged to form a receptacle for the thoracic and abdominal viscera, that at the same time gives protection, allows for changes in size and form, and provides attachments for the muscles whose actions are essential to the proper functioning of these organs. This receptacle is somewhat cylindrical in form, incomplete in the front lower part. It is made up of the spinal column behind, the sternum in front, and the ribs on the front, sides, and back of the upper part.

The Spinal Column.—The spinal column is made up of twenty-six segments to combine flexibility and strength. These segments are vertebræ, either typical or rudimentary, grouped into five divisions. In the neck are seven vertebræ, called cervical; below these are twelve dorsal or thoracic vertebræ, to which the ribs are attached; below these, five lumbar vertebræ, followed by the sacrum and this, by the coccyx.

The Vertebræ.—A vertebra is an irregular bone, having a body in front and an arch (neural) behind.

The body is the large solid portion, somewhat like a half-cylinder, with a concave posterior, and convex anterior and lateral surfaces. The weight of the head and trunk, together with that of the upper extremity is borne on the column of bodies.

The neural arch is joined to the body by processes called pedicles. Continuing from the pedicles are flat plates called laminæ, which with the body complete the borders of the vertebral or spinal foramen through which passes the spinal cord. Supported by the pedicles and laminæ are seven bony processes, one spinous posteriorly, two transverse and four articular. On the upper and lower surfaces of the pedicles are notches, which become parts of intervertebral foramina when two vertebræ are joined together. Through these foramina pass the spinal nerves, branching out from the spinal cord.

The spinous process projects backward in the median line at the junction of the laminæ. The transverse processes project outwardly from the sides, each bearing articular processes near its extremity. These are in pairs, *superior and inferior*, facing in opposite directions, and articulating respectively with those above and below.

This description is of a typical vertebra. With a few exceptions, all these parts are found on every *vertebra*. However, there are in the different regions distinguishing variations.

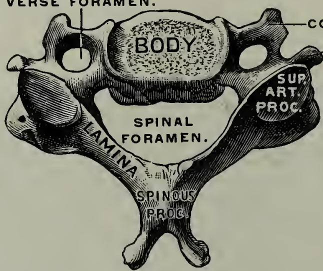


FIG. 40.—Cervical vertebra, viewed from above. (Testut.)

The Cervical Vertebræ.—In the cervical or neck region the seven vertebræ have to provide for a greater amount of movement than elsewhere, so there are certain differences in form. The bodies are smaller and flatter; on the upper surface are lateral lips; on the under surface, an anterior lip; the transverse processes are forked or bifid, with foramina for the passage of the vertebral artery; and the spinous processes are bifid and nearly horizontal. The third, fourth, fifth, and sixth are typical, but the first, second, and seventh are peculiar.

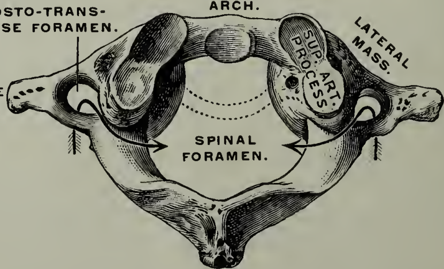


FIG. 41.—The atlas, viewed from above. (Testut.)

The first cervical vertebra, or *atlas*, is directly under the occiput, articulating with it. It has no body or spinous process, and allows the greatest possible freedom of motion between the head and the spinal column. Two arches, dorsal and ventral, connect two lateral

masses. On the upper surface of these masses are large articular surfaces upon which the head rocks back and forth, in the occipito-atloid articulation. The articular facets on the under surface of the lateral masses are for the union with the second cervical vertebra, the *axis*.

The *axis* has a large strong body, on which is fused the body of the atlas, here serving as a pivot around which the atlas carrying the head may rotate. This process is the odontoid (tooth-like).

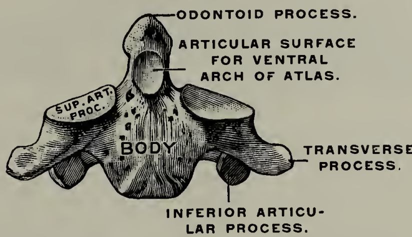


Fig. 42.—The axis, front view. (Testut.)

The seventh cervical vertebra has a long spinous process that is not bifid. It is very prominent, hence its name, the *vertebra prominens*, serving as a landmark. To this is attached the lower part of the ligamentum nuchæ.

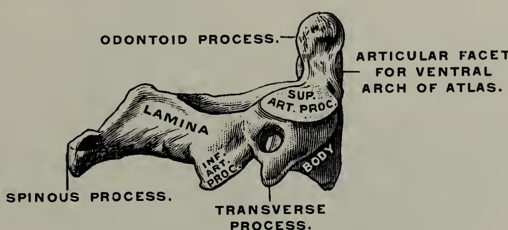


Fig. 43.—The axis, its right side. (Testut.)

The Thoracic Vertebræ.—The next group is the thoracic or *dorsal vertebræ*, distinguished primarily by facets on the bodies for articulation with the head of a rib, and facets on the transverse processes for articulation with the tubercle of a rib. Usually the facets on the bodies are demi-facets on the upper and lower borders, so that with the intervertebral cartilage between the bodies, the head of a rib may set into a sort of socket. The spinous processes project downward and overlap, especially in those near the middle of the group, while the laminæ also overlap. The first and last of this group resemble those of the contiguous groups above and below. The overlapping of spines and laminæ limits extension of the spine very markedly, but does not much interfere with flexion and rotation.

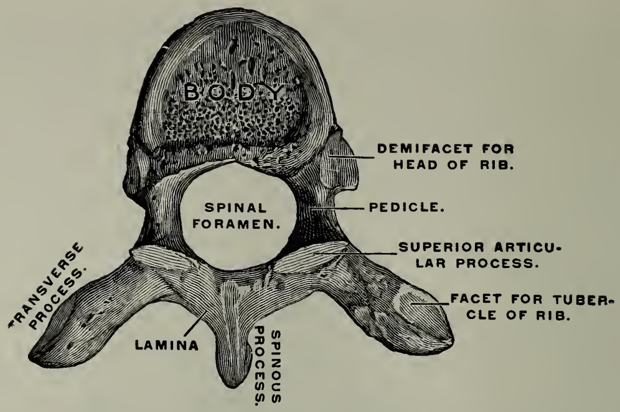


Fig. 44.—A thoracic vertebra, upper surface. (Testut.)

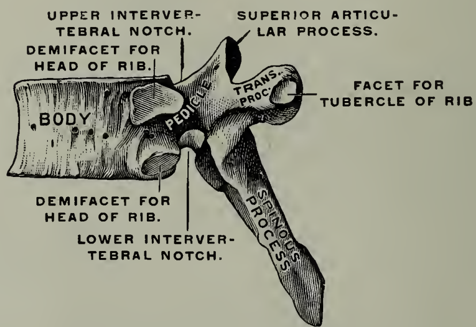


Fig. 45.—Thoracic vertebra, seen from the left side. (Testut.)

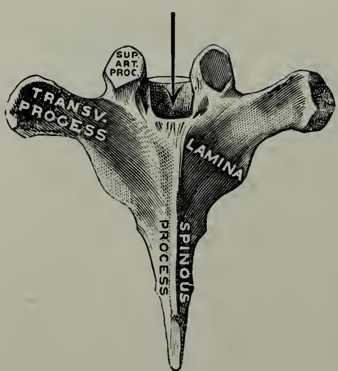


Fig. 46.—Thoracic vertebra, viewed from behind. (Testut.)

The Lumbar Vertebræ.—The lumbar vertebræ are large and heavy looking, having large oval bodies, long transverse processes, and

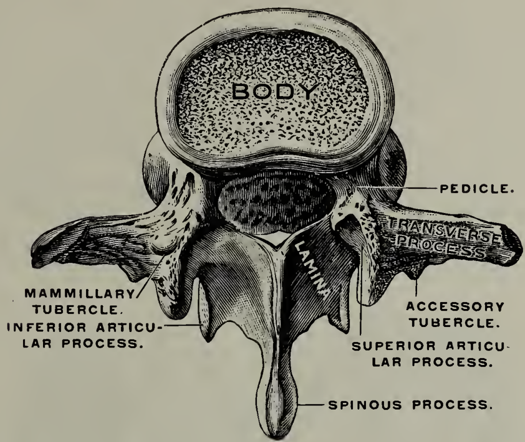


FIG. 47.—Lumbar vertebra, viewed from above. (Testut.)

square, strong looking spinous processes. They have neither bifid spines nor foramina in the transverse processes, which would distinguish them from the cervical vertebræ, nor articular facets on

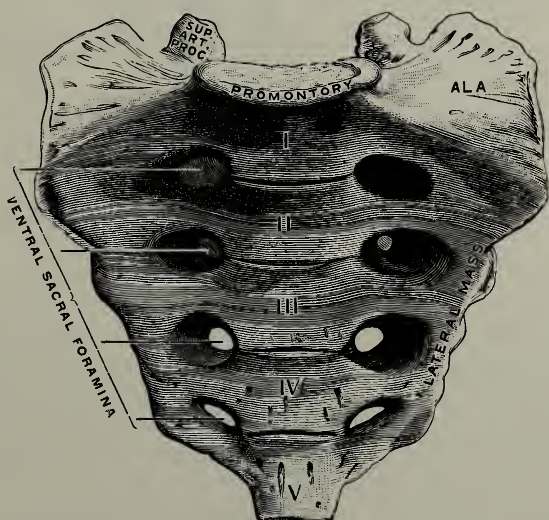


FIG. 48.—The sacrum, ventral view. (Testut.)

the body and transverse processes, which distinguishes them from the thoracic group.

The Sacrum.—The sacrum articulates with the last lumbar vertebra, and gives support to the spine as a whole. It is a modification of vertebræ, five seemingly being fused together, and lacking various characteristics of the typical vertebra. The bone is triangular in shape, widest above and tapering below, where it articulates with the upper bone of the coccyx. The sacrum lies obliquely, with the upper surface inclined forward, and forming an acute angle with the last lumbar vertebra. The upper part is called the promontory, with the alæ or wings on the sides. On each side are four large foramina, going through from front to back for the passage of the sacral nerves. The front of the bone is relatively smooth,

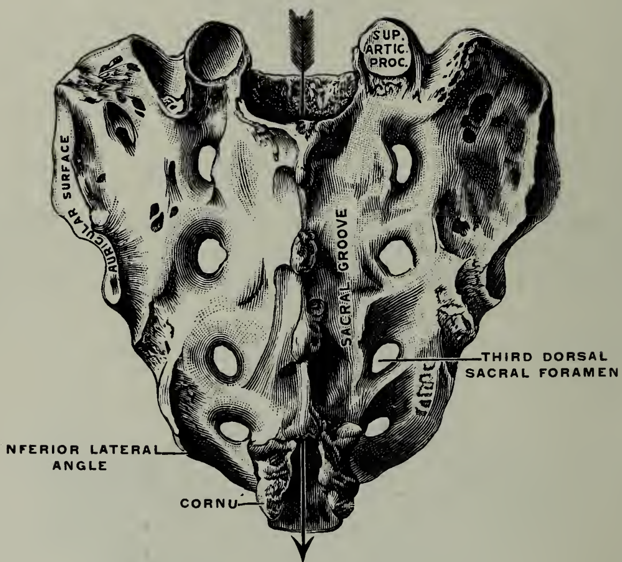


FIG. 49.—The sacrum, dorsal view. (Testut.)

but the dorsal aspect presents much roughness for the attachment of muscles and ligaments. The rudimentary spinous processes form a rough ridge. Laterally, are two ear-shaped articular surfaces, called the *auricular surfaces,* which articulate with the ilium. This articulation of the two bones completes the bowl-shaped cavity known as the bony pelvis.

The *coccyx* consists of a variable number of small bones, rudimentary vertebræ, of triangular shape, tapering downward. In early life there may be from three to five of these, but later they are apt to fuse together. They serve for the attachment of several large muscles and aponeuroses.

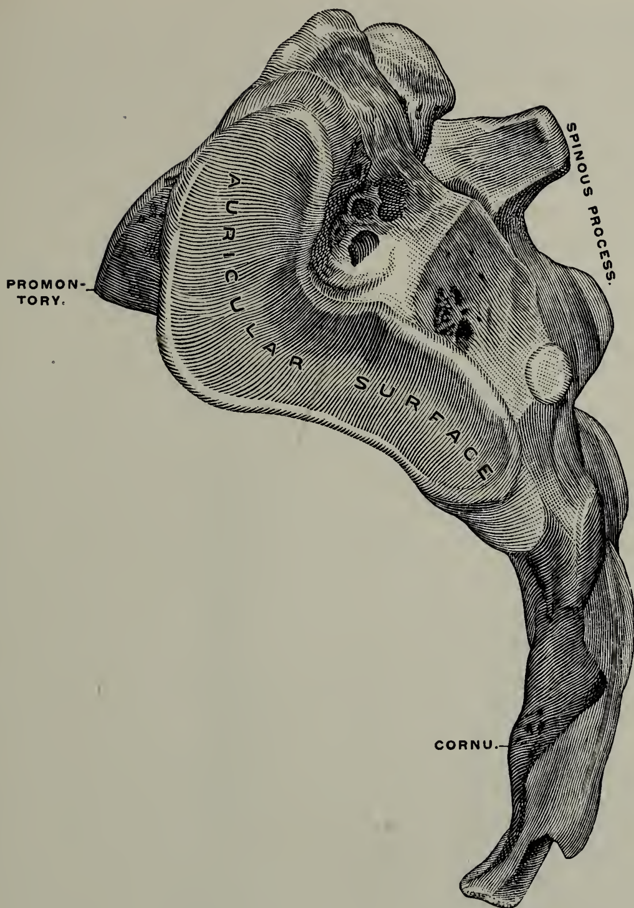


Fig. 50.—The sacrum, its left side. (Albinus.)

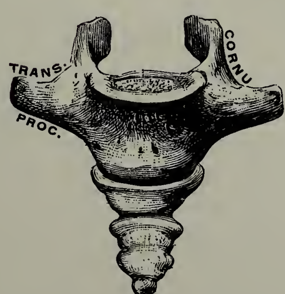


Fig. 51.—The coccyx, ventral surface. (Testut.)

The Spine as a Whole.—The spinal column is the central axis of the body. It is in the median line, and the posterior part of the trunk. It supports the head, the ribs, and the upper extremities. Through the spinal column, the weight of these parts is transmitted downward. The sacrum articulates with the hip bones, while the lower extremities articulate with the latter.

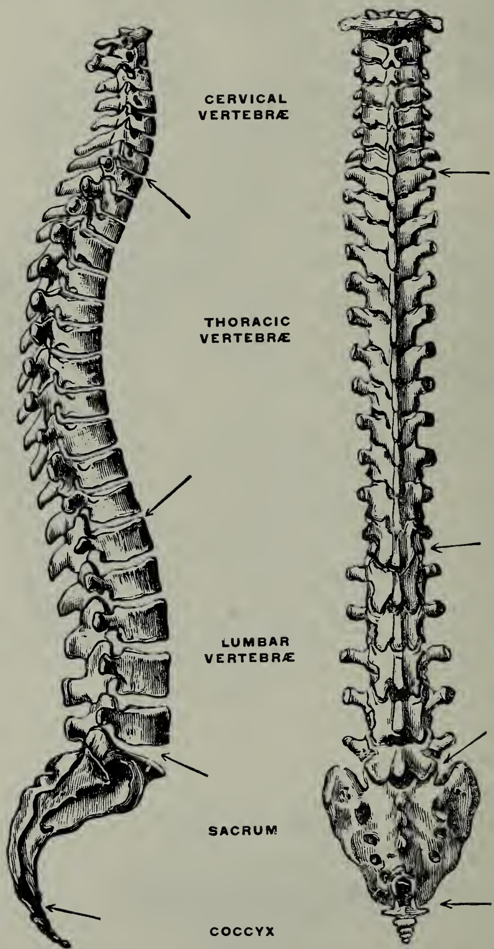


Fig. 52.—The spinal column, right lateral view and dorsal view. (Testut.)

The average length of the spine is 27 or 28 inches, of which about one-quarter is made up of the fibro-cartilaginous intervertebral disks. The view from the side shows four curves from before backward. These are convex forward in the cervical and lumbar regions; convex backward in the thoracic and sacral regions. The latter two

curves are present at birth, but the other two are developed as the child assumes an upright position. The shape of the bodies determines the sacral and thoracic curves. In the other two regions the intervertebral disks determine the extent of the curve. These curves add much to the strength and elasticity of the column, lessening jars. No lateral curve exists normally. It should be observed that the anterior-posterior curves are mutually dependent. Any increase in the convexity of the dorsal curve is compensated by an increase in the lumbar concavity.

From the standpoint of correct posture the relations of the different parts of the spinal column are exceedingly important. A large number of ligaments and muscles are attached to the vertebræ, connecting the spine to the head, to the trunk, to the upper and lower extremities. As the muscles attached to the spine connect it with every other part of the body, movements elsewhere have an influence upon its position, producing lateral deviations, more or less temporary. At the junction of the cervical and dorsal spines there is a dividing point between several important muscles, with resulting weakness. In the same way, at the junction of the dorsal and lumbar spines, this feature is much more marked, with the additional fact that there a relatively fixed part, the thorax, joins the most movable part, the lumbar spine. A long leverage above and below with the width of the spine less than in either locality contributes to the weakness. (Fig. 52.)

Note.—This is easily demonstrated by holding the carcass of a fowl with one hand on the upper part, the other hand on the lower part of the trunk and bending the body backward. The spine gives way with startling ease at the dorso-lumbar junction.

The various parts of the vertebra complete their growth and ossification at various times, ending about the twenty-fifth year.

THE BONES OF THE THORAX.

The thorax is a bony cage, roughly cone-shaped, with the top formed by the first rib facing forward and upward. The much larger base is formed by the edges of the lower six ribs converging to the xiphoid cartilage and forming the *subcostal angle.*

Note.—Look up the studies made at the Central School of Hygiene at the Y. W. C. A., New York, in reference to the significance of the width of the subcostal angle as regards mental and vital ability.

The backward curve of the ribs forms a broad furrow on the back, on each side of the spinal column. This is the *vertebral groove* in which rests some of the erector spinæ group of muscles. The back of the thorax is flatter than the front and allows the supine position

in man, as distinguished from the rounded backs of quadrupeds which do not allow the supine position.

At birth the thorax resembles that of quadrupeds more than that of an adult human being, being more barrel-shaped and less broad in the transverse direction. The angles have not been developed and the ribs are less curved. As time goes on, the thorax broadens, and the back becomes more flat. An infant, placed on its back, rolls about.

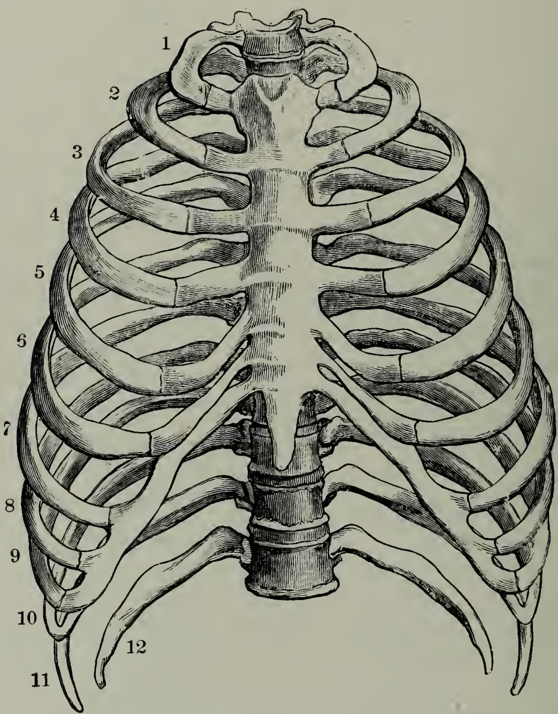


FIG. 53.—The skeleton of the thorax, front view. (Testut.)

The bodies of the vertebræ encroach upon the cavity of the thorax so the inside diameter is less than that taken externally. As far down as the seventh or even lower, the ribs are increasingly more oblique. This makes the intercostal spaces wider at the side than at the back. In inspiration they are wider than after expiration thus increasing the capacity of the thorax.

The thorax contains the organs of respiration and circulation, and not only protects them, but allows the movements necessary to their proper functioning. While each rib and vertebra has but a small range of motion, the aggregate is considerable.

Many muscles, moving the arms, trunk and head and giving support to the abdominal viscera, are attached to the thorax.

The Sternum.—The sternum or breast bone is on the front wall of the thorax, connecting with the ribs and the clavicle. It is a long thin bone, wider above than below, having at the lower end a prolongation of cartilage called the *xiphoid* or *ensiform cartilage* or process. The upper part of the bone is thicker and wider and is

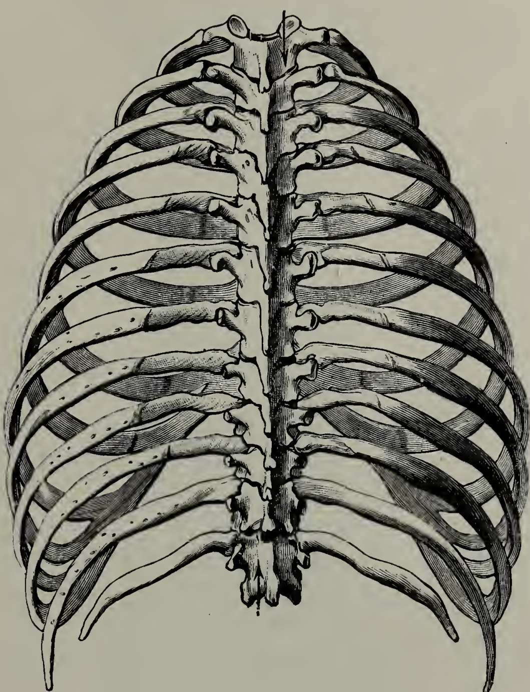


Fig. 54—The skeleton of the thorax, dorsal view. (Testut.)

called the *manubrium* or "handle." It is united to the lower part by fibrocartilage and remains distinct through life. The lower part, the *gladiolus* or "little sword" in early life consists of four segments which later unite into one piece.

The *manubrium* has a notch on its upper surface ("interclavicular notch") and two articular surfaces on the lateral angles for articulation with the clavicles. At the widest part on the side, are articular facets for its union with the cartilage of the first rib. At the junction of the manubrium and gladiolus is a transverse ridge indicating the level of the second rib, that serves as a landmark in

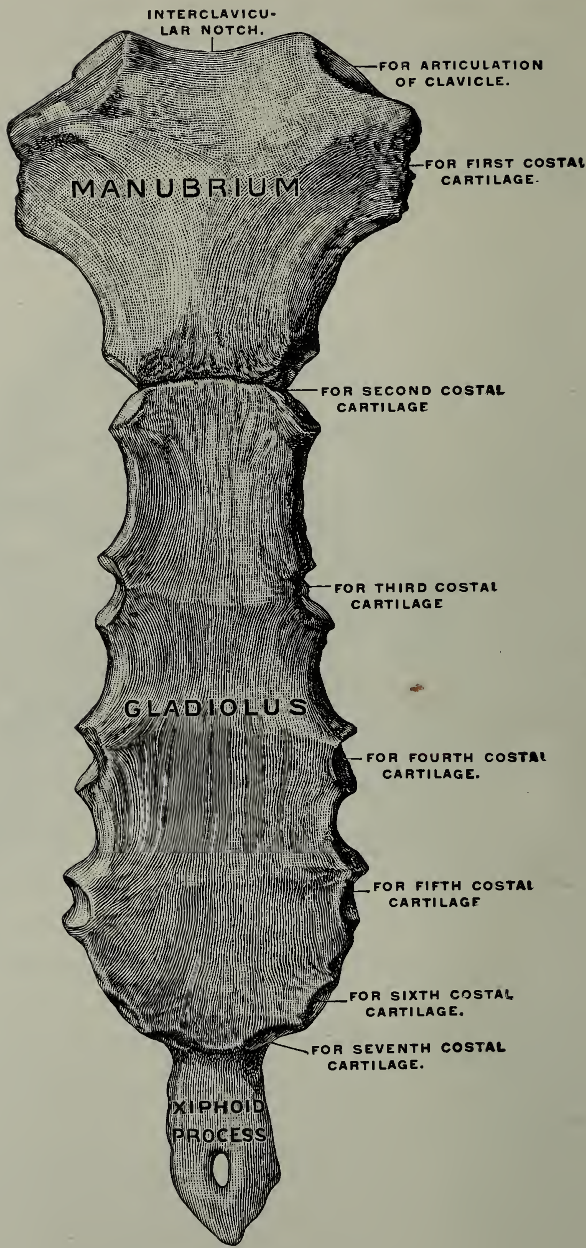


Fig. 55.—The sternum, ventral aspect. (Spalteholz.)

locating the valves of the heart. Articular facets laterally give attachment to the second rib, while the next five articulate with the gladiolus. Thus seven ribs are directly joined to the sternum.

The muscles attached to the sternum are, pectoralis major, sternomastoideus, rectus abdominis, the aponeurosis of the transversus abdominis and obliquus internus abdominis, the sternohyoid, the sternothyroid, the triangularis sterni, the internal intercostals and the diaphragm.

The Ribs.—Twelve pairs of ribs, prolonged at the front end by plates of cartilage, form the larger part of the walls of the thorax. These plates of hyaline cartilage are called *costal cartilages.* They increase the elasticity of the thorax, also serving as buffers to take up the force of blows. The upper seven pairs of ribs are attached directly to the sternum, and are considered true ribs (or sternal ribs), while the next three being indirectly attached to the sternum are

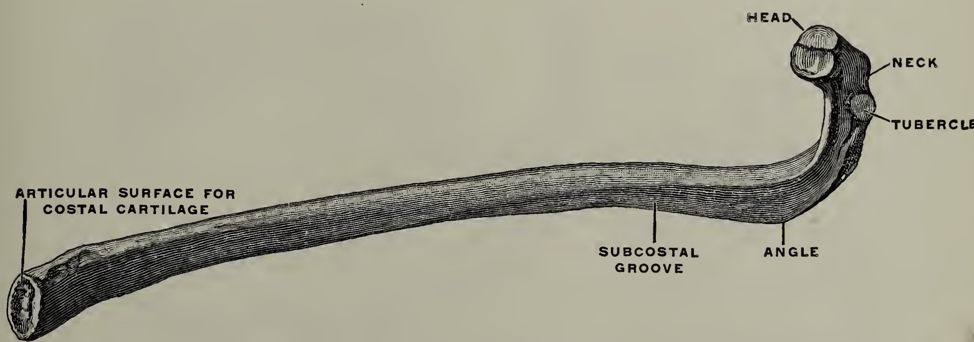


Fig. 56.—The sixth rib of the right side viewed from the middle line of the body. (Spalteholz.)

called false (or asternal) ribs. The last two pairs are attached to the vertebræ only and are called "floating ribs."

The length of the ribs increases from the first to the eighth, then decreases to the twelfth.

A rib is a "long bone," having a shaft and two extremities. The middle eight ribs are typical, but the first two and last two are peculiar. At the vertebral end of a typical rib is the enlarged *head* which is joined by a constricted neck to the shaft. The *head* articulates with the bodies of the vertebræ. Just where the neck joins the shaft is a prominence of bone called the *tubercle.* This articulates with the transverse process of a vertebra. The shaft begins at the tubercle and extends to the sternal end where a cup-like cavity receives the costal cartilage.

The shaft of the rib is curved in three directions. Looking at the back of the thorax it is seen that there is a relative fulness to the

curve of the ribs, and that where they begin to form the side wall of the chest a sudden bend is made in the curvature. This bend is the *angle*. As the ribs proceed downward, the angle takes place at a greater distance from the spine. The curvature of the front end is flatter. In addition to these curves on the flat, the shaft of the lower ten ribs at the angle is curved on the horizontal axis so if the rib rests upon the lower border of the shaft the vertebral end curves upward. This curve increases from the third to the seventh ribs, then decreases to the twelfth. This twisting is of great importance in providing for an increase of the lateral and antero-posterior diameters of the thorax in respiration.

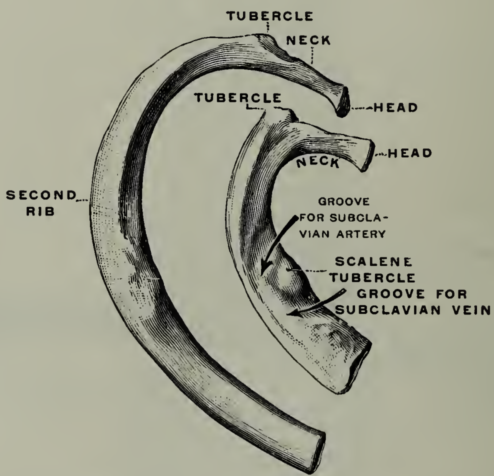


FIG. 57.—The first and second ribs of the right side, viewed from above. (Testut.)

Peculiar Ribs.—The first rib is short, broad and so placed that the surfaces face up and down. It affords attachment to the scalenus anticus and medius muscles, and to the first digitation of the serratus magnus muscle.

The second rib is longer and lacks the curve on the horizontal axis. It gives attachment to the scalenus posticus and to the second and third digitations of the serratus magnus muscle.

The scaleni being muscles of inspiration act by raising these two upper ribs thus providing a firm base for the elevation of the other ribs by the intercostal muscles.

The eleventh and twelfth ribs are short and lack several of the characteristics of a typical rib, as tubercle and angle.

The costal cartilages are hyaline cartilage which prolong the ribs at the sternal ends, fitting into cup-like depressions on the shaft and the first seven articulating with the sternum. Their direction is upward and inward and the length increases to the seventh rib.

The cartilages of the eighth, ninth and tenth ribs unite with each other and the upper part is joined to the cartilage of the seventh rib. The cartilages of the eleventh and twelfth ribs form smooth ends. The costal cartilages give attachment to most of the muscles mentioned above as being attached to the sternum.

The Hyoid.—The hyoid is a small, light, somewhat horseshoe-shaped bone in the front part of the neck below the chin. To it the tongue and many muscles of deglutition are attached.

THE BONES OF THE UPPER EXTREMITY.

The upper extremity consists of the arm, forearm and hand, connected to the trunk by the shoulder girdle. This consists of the clavicle and scapula.

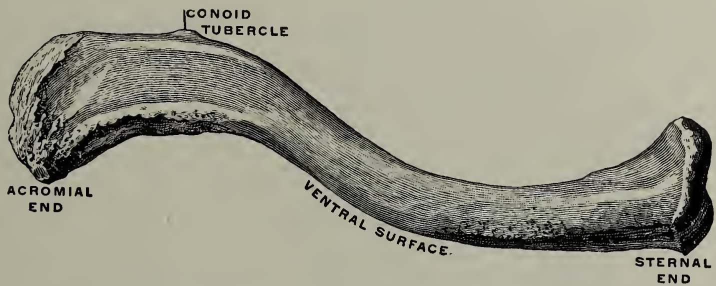


Fig. 58.—The right clavicle, upper surface. (Spalteholz.)

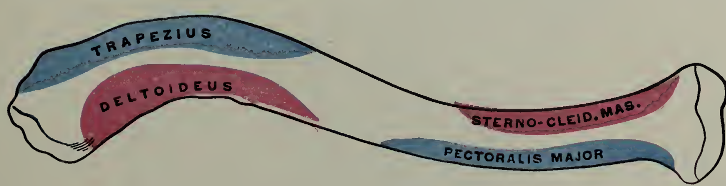


Fig. 59.—Areas of muscular attachment, upper surface of right clavicle. (Gerrish.)

THE SHOULDER GIRDLE.

The Clavicle.—The clavicle or collar-bone is a long bone having a shaft and two extremities. It is curved like the italic letter *f*, and extends across the upper part of the chest, horizontally from the notch on the manubrium to the acromion process of the scapula, articulating with these two surfaces. The inner two-thirds is cylindrical in form, while the outer third is flattened from above downward and curves backward. The shaft of the bone presents on the superior and anterior aspect of the inner half a rough place for the attachment of the sternomastoideus, and below, one for the pectoralis major. The posterior, sternal surface gives attachment

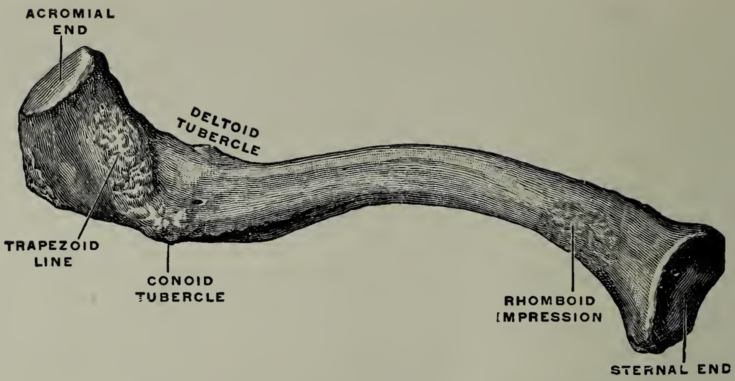


FIG. 60.—The right clavicle, under surface. (Spalteholz.)

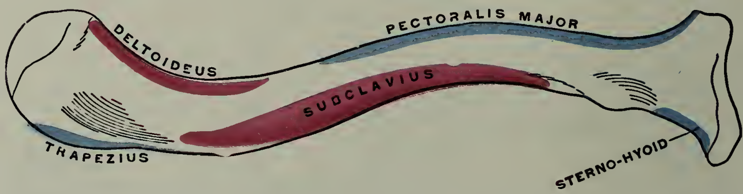


FIG. 61.—Areas of muscular attachment, lower surface of right clavicle. (Gerrish.)

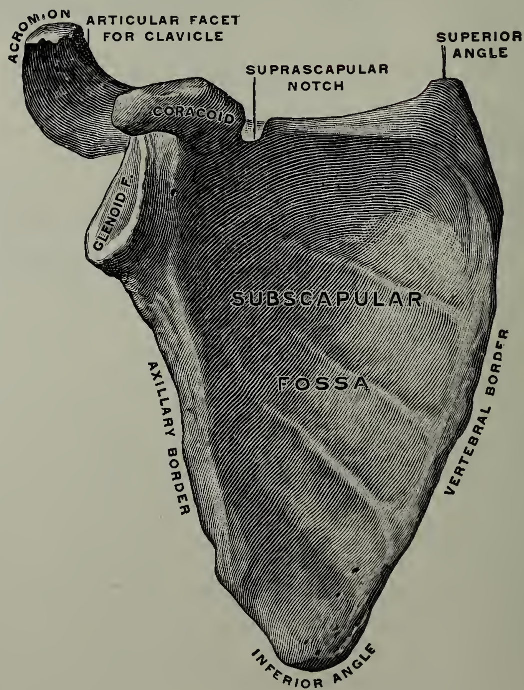


FIG. 62.—The right scapula, ventral view. (Spalteholz.)

to the sternohyoid muscle. On the outer third are rough places on the superior surface for the deltoid muscle in front, and the trapezius muscle behind.

The inferior surface at the sternal end presents the rhomboid impression for the attachment of the rhomboid ligament, and the subclavian groove for the subclavian muscle. Throughout the greater part of its length the clavicle is subcutaneous, so its outline may be followed by the finger. During their contraction the extent of the muscles attached to it may be felt.

This method of studying muscles should be used whenever possible.

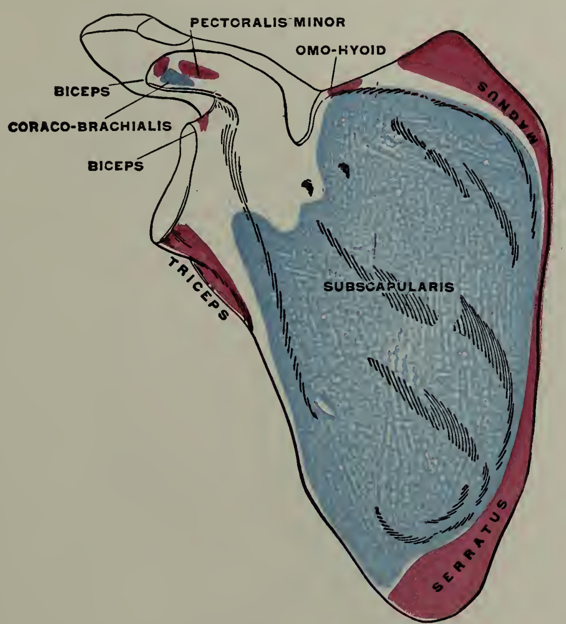


Fig. 63.—Areas of muscular attachment, ventral surface of right scapula. (Gerrish.)

The Scapula.—The scapula or shoulder-blade is a large flat bone, triangular in shape, on the upper posterior part of the thorax. It presents three angles, external, superior, and inferior; three borders, superior, vertebral, and axillary; and two surfaces, dorsal and ventral. It extends from the second to the seventh ribs, and from its articulation with the clavicle at the peak of the shoulder to within 2 inches of the spine. The lower border of the inferior angle is in a horizontal line with the seventh thoracic spine.

The external angle or head has an articular surface, the glenoid fossa, for articulation with the humerus. Projecting from it toward the front is a beak-like process, the coracoid process. This process is covered with an aponeurosis which gives attachment to the pec-

toralis minor, the coraco-brachialis and the short head of the biceps muscle. Above the glenoid fossa is a rough impression for the tendon of the long head of the biceps muscle, while below the fossa the long head of the triceps muscle is attached. The glenoid fossa, covered with cartilage in the recent state looks upward, outward and forward.

The ventral surface shows a shallow fossa, with several ridges crossing it, for the reception of the subscapular muscle. Along the vertebral border of this surface is a rough ridge for the serratus magnus muscle.

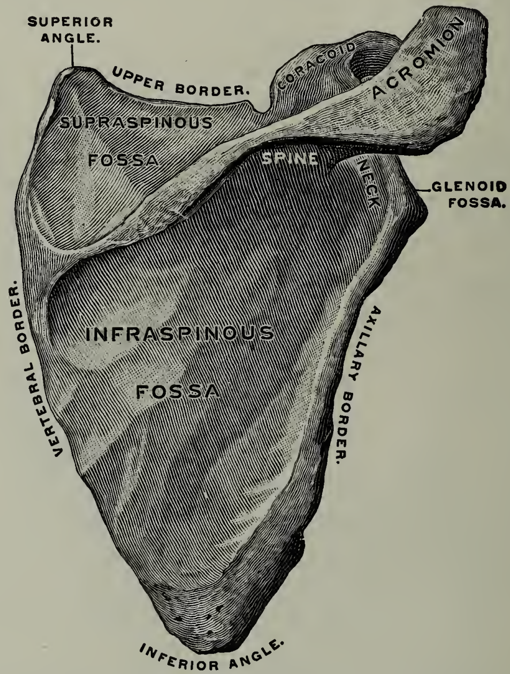


Fig. 64.—The right scapula, dorsal view. (Spalteholz.)

The dorsal surface presents a prominent ridge, the *spine*, which passes from the vertebral border, about one-third of the distance down, going across the bone diagonally upward, becoming heavier and wider, until near the external angle it leaves the surface, and continues as a broad, rough prominence, the acromion process. The posterior free border of the spine is thick and curved. It is called the crest, with upper and lower lips. Above the spine is a fossa, the supraspinous, giving attachment to the supraspinatus muscle. The surface below the spine, the infraspinous fossa, is depressed, and gives attachment to the infraspinatus muscle. To the upper lip of the crest is attached the trapezius muscle, while to

the lower lip is attached the deltoid muscle. The external or axillary border gives attachment above to the teres minor, and below to the teres major muscles. The internal or vertebral border of the dorsal surface gives attachment above to the rhomboideus minor, and below to the rhomboideus major muscles. The superior angle and the uppermost part of the vertebral border give attachment to the levator anguli scapulæ, while the inferior angle usually has the latissimus dorsi muscle attached.

The superior border of the scapula is concave, extending from the superior angle to the base of the coracoid process. It presents the suprascapular notch, through which passes the suprascapular nerve.

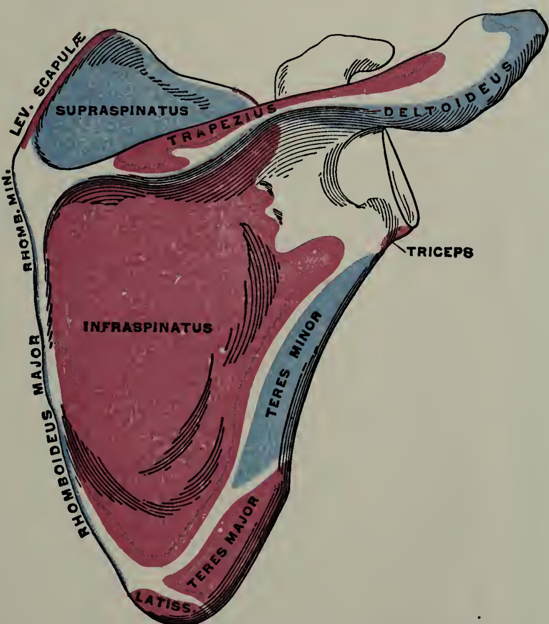


FIG. 65.—Areas of muscular attachment, dorsal surface of right scapula. (Gerrish.)

To the border adjacent, the omohyoid muscle is inserted. This completes a total of seventeen muscles which arise from the scapula, passing in every direction, anchoring it and guarding the shoulder-joint, besides providing for movements of adjacent parts.

The only bony connection of the shoulder girdle with the trunk is at the sterno-clavicular articulation.

Ossification.—The bony union of the sections of the clavicle and the scapula occurs about the twenty-fifth year.

The Humerus.—The humerus (brachium), or the bone of the arm is a long bone with a shaft and two extremities. The upper extremity presents a rounded head, covered with cartilage in the recent

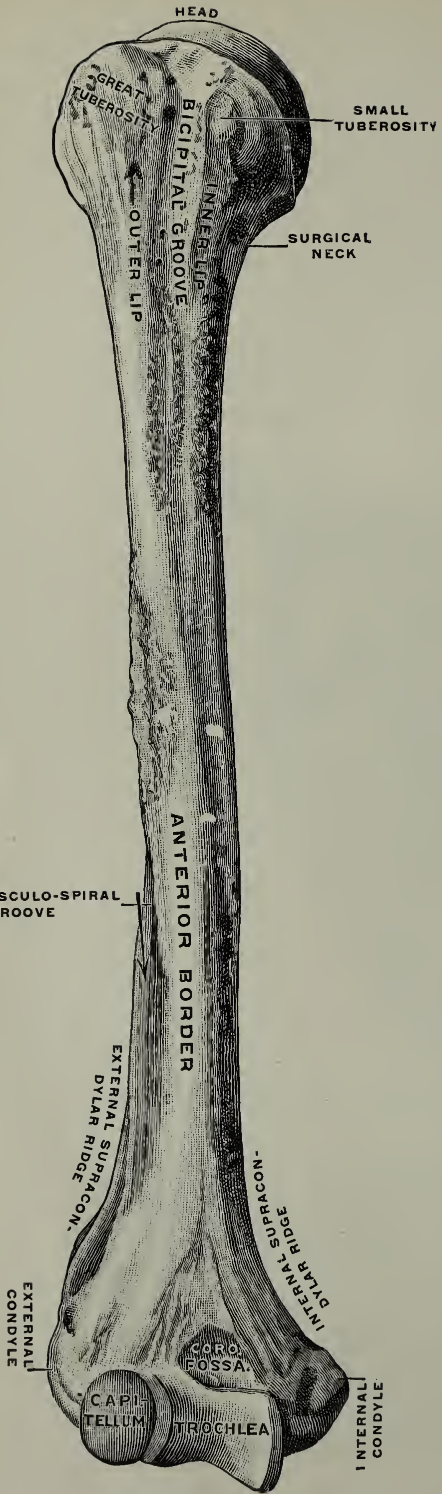


Fig. 66.—The right humerus, front view. (Testut.)

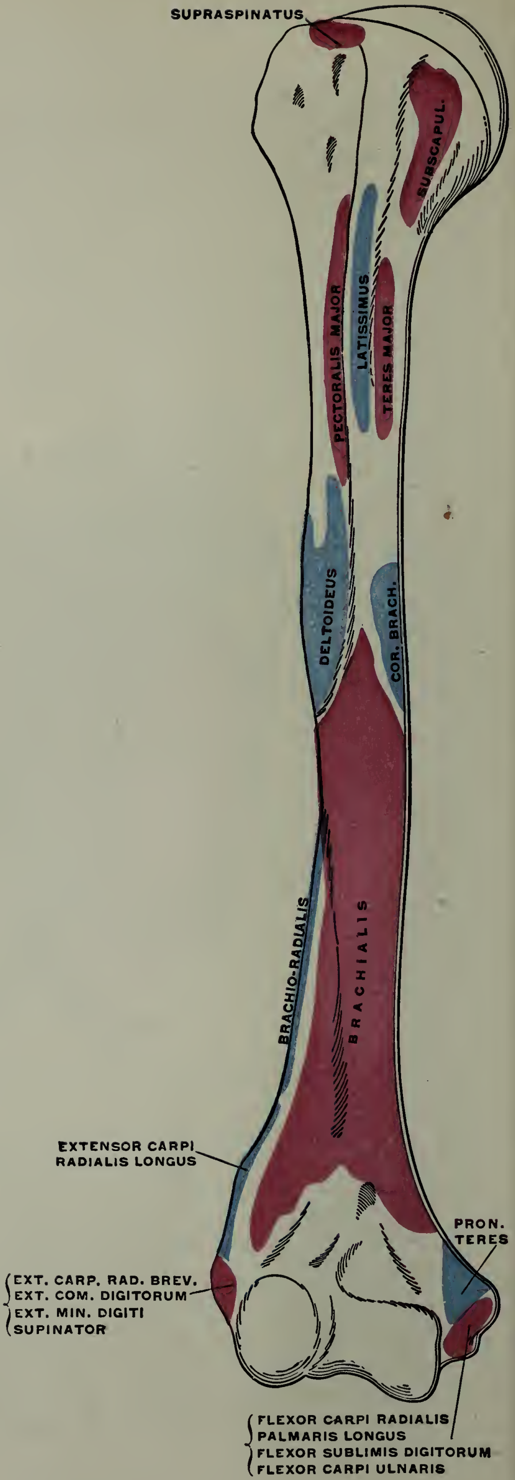


Fig 67.—Areas of muscular attachment, ventral aspect of right humerus. (Gerrish.)

FIG. 68.—The right humerus, rear view. (Testut.)

FIG. 69.—Areas of muscular attachment, dorsal surface of right humerus. (Gerrish.)

state, and articulating with the glenoid fossa of the scapula. The head is directed upward, inward, and backward, at an angle of about 130 degrees. Just below the head is a constriction of the bone which is called the "anatomical neck," in distinction from the "surgical neck" below the tuberosities. (The surgical neck is so-called for convenience in designating the locality in case of fracture). The anatomical neck gives attachment to the capsular ligament of the shoulder-joint. Below this two prominences are separated by a groove, the bicipital groove. The larger, and outer prominence is the greater tuberosity; the smaller, and inner, the lesser tuberosity. On the latter is inserted the subscapularis muscle. On the greater tuberosity are three facets, one being above, the other two posterior. To the upper facet is attached the supraspinatus muscle; to the middle facet the infraspinatus muscle, and to the lowermost facet the teres minor muscle. Through the bicipital groove runs the tendon of the long head of the biceps muscle to be attached above the glenoid fossa. The groove has two lips, to the inner of which the teres major muscle is attached, and on the floor of the groove, and to the inner lip, the latissimus dorsi muscle is attached. To the outer, and anterior lip, the tendon of the pectoralis major muscle is attached.

The shaft of the humerus is cylindrical above, prismoidal and flattened in the lower part. The bone has three surfaces, internal, external, and dorsal, separated by internal, external, and anterior borders. The internal border has a rough place near its center for the coraco-brachialis muscle. The lower part of the border becomes the internal supracondylar ridge, ending in the internal condyle. The external border extending downward from the greater tuberosity is more marked at the lower end, becoming the external supracondylar ridge, to which in the upper two-thirds is attached the brachio-radialis and below that the extensor carpi radialis longus muscle. The anterior border begins at the outer lip of the bicipital groove, and passes down to between the capitellum and trochlea. Just above the center of the bone on the external surface is a very rough impression for the attachment of the deltoid muscle. Below this, passing across the external border, a groove, the musculo-spiral groove, winds around the shaft of the bone downward and forward. In the groove lies the musculo-spiral nerve. Above the groove, on the dorsal surface of the humerus the external head of the triceps muscle is attached, while to the surface below, the internal head is attached. To the lower half of the anterior surface is attached the brachialis muscle.

The lower extremity of the humerus is flattened from before backward, and curved forward, with prominent processes, the condyles, on each side. These are subcutaneous. The more prominent, the *internal* condyle gives attachment to a group of flexor and pro-

nator muscles, namely the flexor carpi radialis, flexor carpi ulnaris, palmaris longus, flexor sublimis digitorum, and pronator teres. The *external* condyle is less prominent and gives attachment to a group of *extensor* muscles and supinators, namely, the extensor carpi radialis brevis, extensor communis digitorum, extensor minimi digiti, extensor carpi ulnaris, supinator, and the anconeus.

Between the condyles is an articular surface, divided into two parts. The larger inner surface is the trochlea (pulley), which articulates with the head of the ulna. Above this in front is the coronoid fossa receiving the coronoid process of the ulna in forced flexion of the forearm. Back of the trochlea is the olecranon fossa, receiving the olecranon process of the ulna in extension of the forearm. The small inner part of the articular surface is the capitellum, for articulation with the head of the radius.

Ossification:—The lower epiphysis unites with the shaft about the eighteenth year. The upper union occurs two years later.

THE BONES OF THE FOREARM.

The bones of the forearm comprise the ulna and the radius, placed side by side, below the arm.

The Ulna.—The ulna is the longer, and is placed on the inner side. It presents a shaft and two extremities.

The upper extremity is thickest, and shows an articular surface, curved forward, called the greater sigmoid cavity. This articulates with the trochlea of the humerus. Below this is the coronoid process which gives attachment to the brachialis and to slips from the flexor sublimis digitorum, pronator teres, and the flexor longus pollicis muscles. Posteriorly is the heavy olecranon process, the highest part of the bone. On the upper surface of this process the triceps muscle is attached. The olecranon is mostly subcutaneous, and is the most prominent part of the elbow. Continuous with the greater sigmoid cavity, on the outer side, is a smaller articular surface, the lesser sigmoid cavity, in which the head of the radius turns in pronation and supination of the forearm.

The shaft becomes rounded as it descends, though the upper part is triangular, showing definitely three borders and three surfaces. The external or interosseous border gives attachment to the interosseous membrane, and divides into two lines above, which pass to the ends of the lesser sigmoid cavity, enclosing a triangular space on which the supinator muscle is attached. The anterior surface gives origin to the flexor profundus digitorum muscle in the upper three-fourths. The pronator quadratus muscle covers the lower fourth. The posterior border is partly subcutaneous, and gives origin to an aponeurosis common to the extensor carpi ulnaris, flexor carpi ulnaris, and flexor profundus digitorum muscles. The

internal surface in the upper part gives attachment to the flexor profundus digitorum muscle. The upper fourth of the dorsal surface shows a triangular area on which is inserted the anconeus muscle. Below this, on the inner side, is an attachment of the extensor carpi ulnaris muscle, while on the outer part of the surface, from above downward, are the extensor ossis metacarpi pollicis, extensor longus pollicis, and extensor indicis muscles.

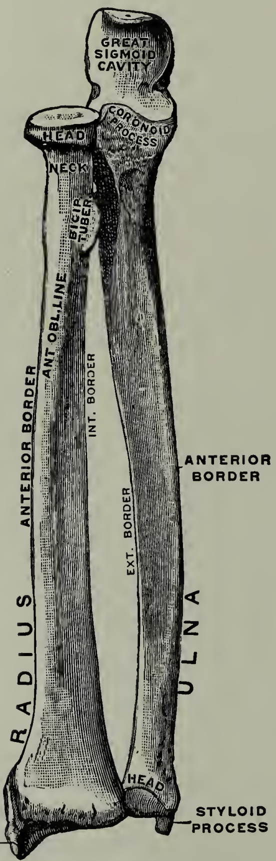


Fig. 70.—The bones of the right forearm, ventral view. (Testut.)

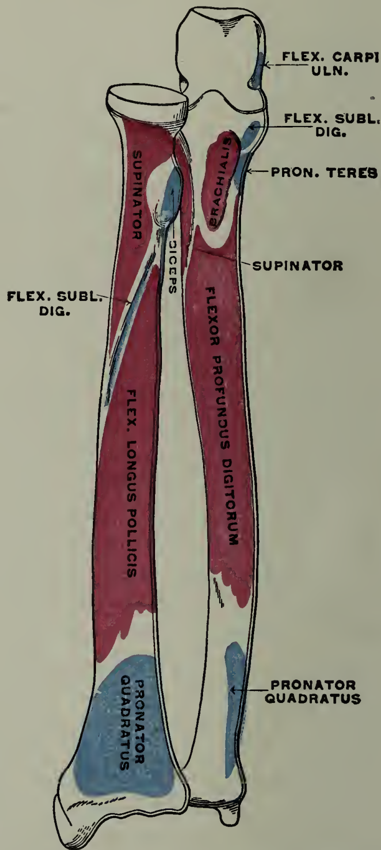


Fig. 71.—Areas of muscular attachment, ventral aspect of the radius and ulna. (Gerrish.)

The lower extremity is small with a rounded head, the lower surface of which moves upon the triangular fibrocartilage of the wrist-joint. On the outer side is a facet that articulates with the sigmoid cavity of the radius. On the inner side, the bone is prolonged downward as the styloid process.

The Radius.—The radius takes but little part in the elbow-joint, but is concerned in the wrist-joint. The upper extremity has a head, somewhat disk-shaped, with a cup-like cavity above, which articulates with the capitellum of the humerus. The side of the head articulates with the lesser sigmoid cavity of the ulna. Below the head is a rough prominence, the bicipital tuberosity, to which the tendon of the biceps muscle is attached.

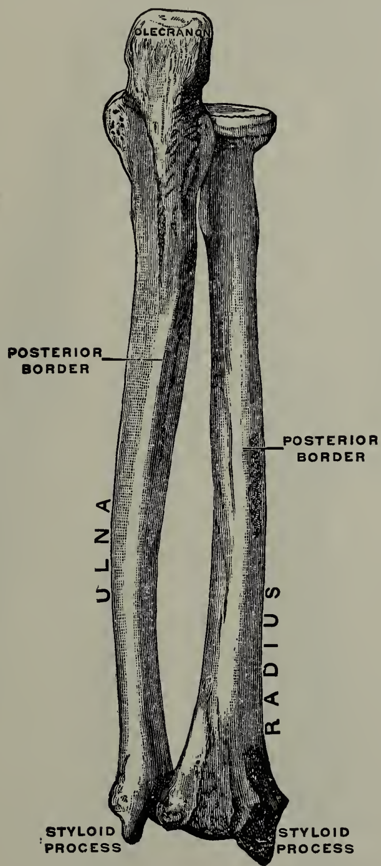


Fig. 72.—The bones of the right forearm, dorsal view. (Testut.)

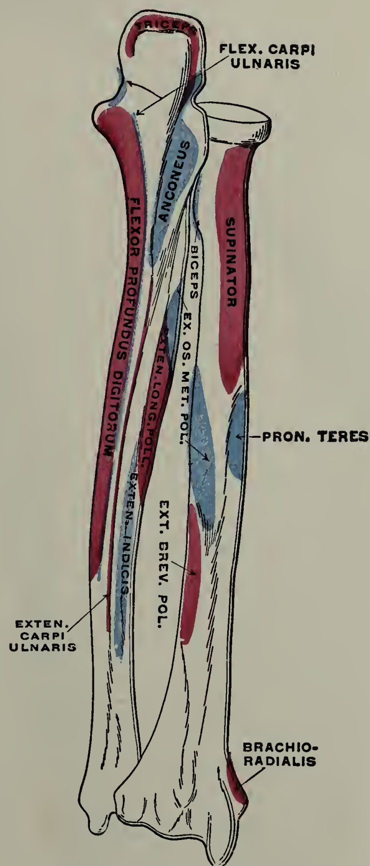


Fig. 73.—Areas of muscular attachment, dorsal aspect of radius and ulna. (Gerrish.)

The shaft of the radius is triangular and increases to a much greater size below. It presents three surfaces and three borders. To the internal border is attached the interosseous membrane. Passing from the bicipital tuberosity outward on the ventral surface is an oblique line which gives attachment to the flexor sublimis

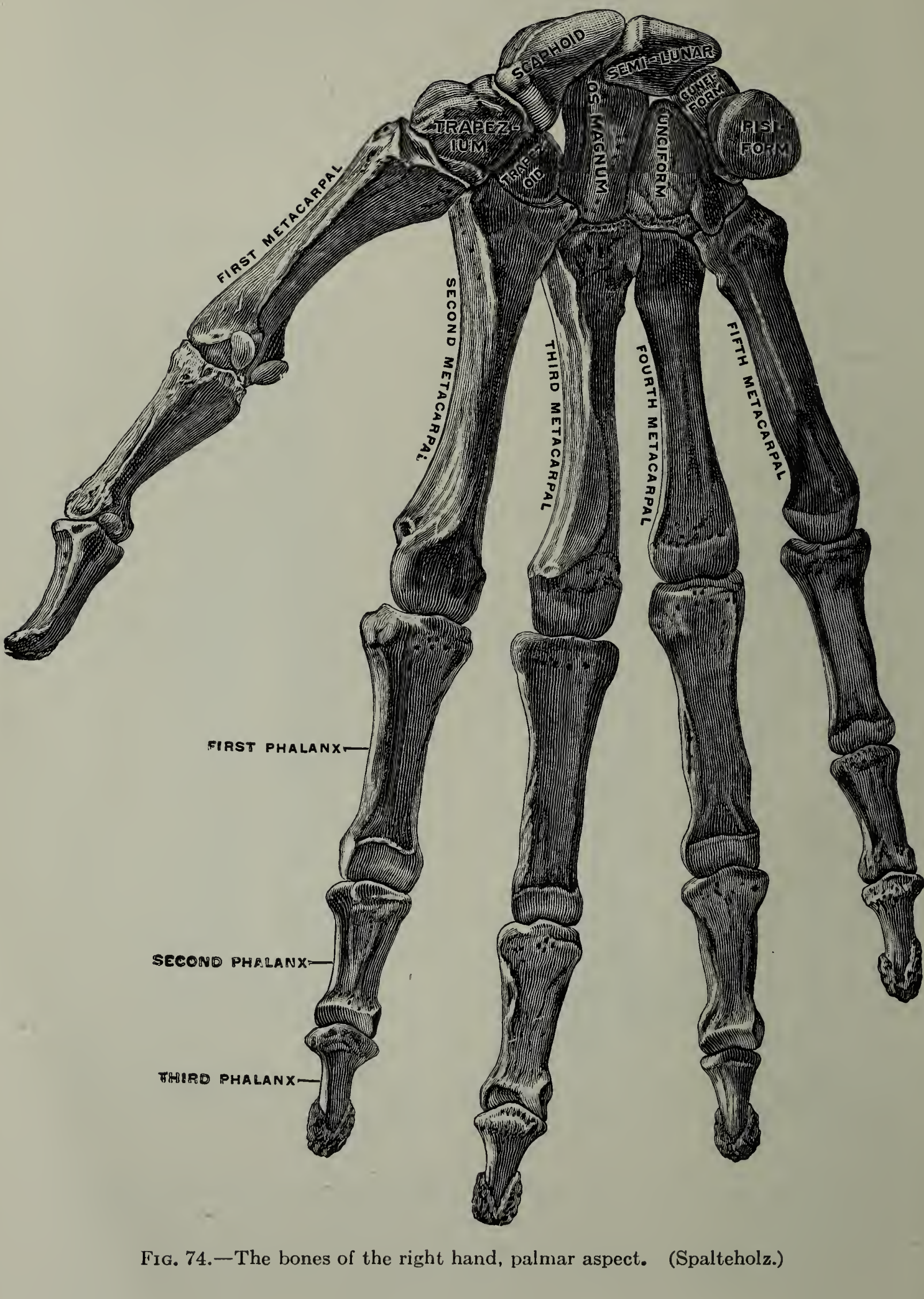


Fig. 74.—The bones of the right hand, palmar aspect. (Spalteholz.)

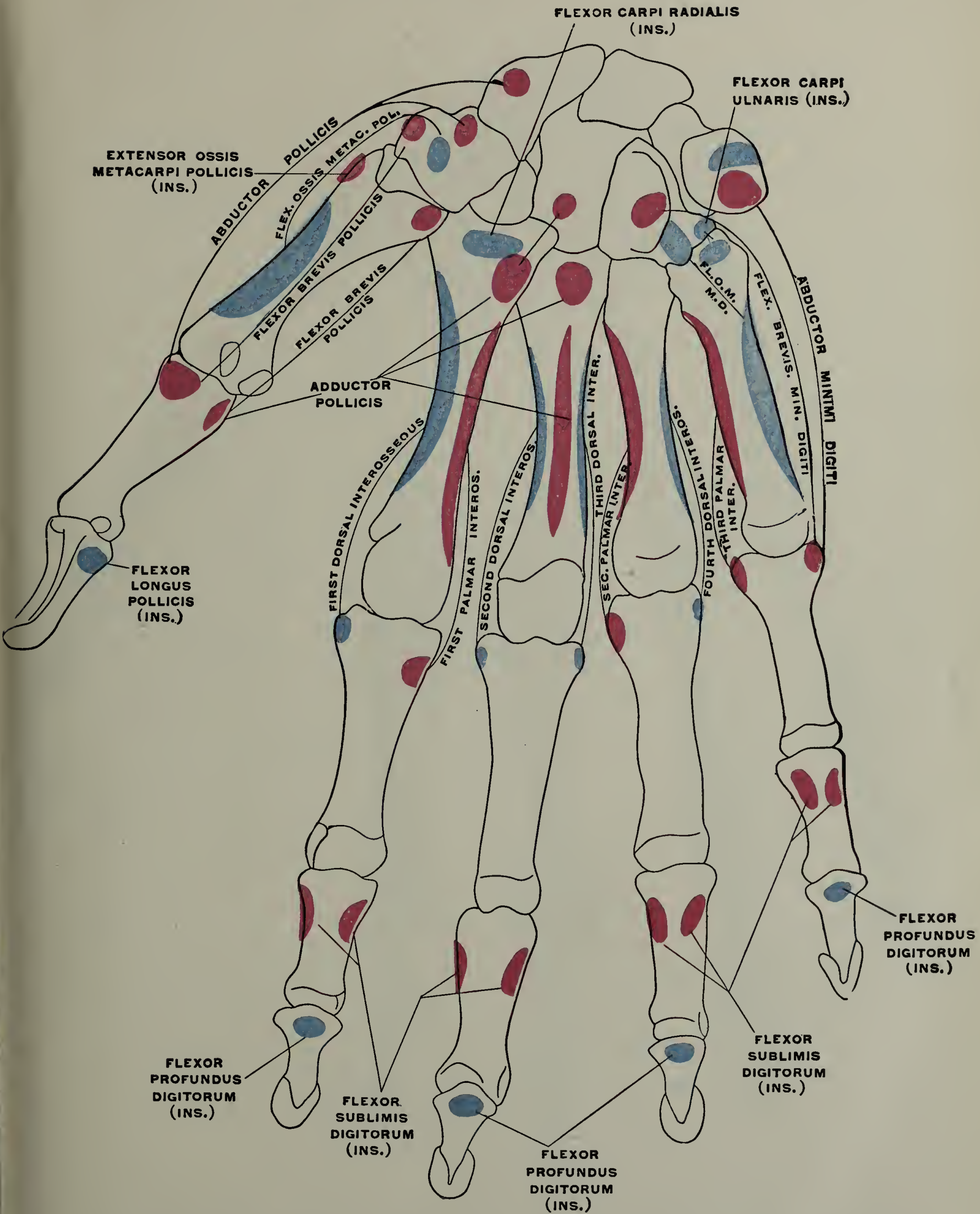


FIG. 75.—Areas of muscular attachment on the palmar surface of the bones of the hand. Where the areas of origin and insertion are both presented they are in the same color. INS., insertion; FL.O.M.M.D., flexor ossis metacarpi minimi digiti. (Gerrish.)

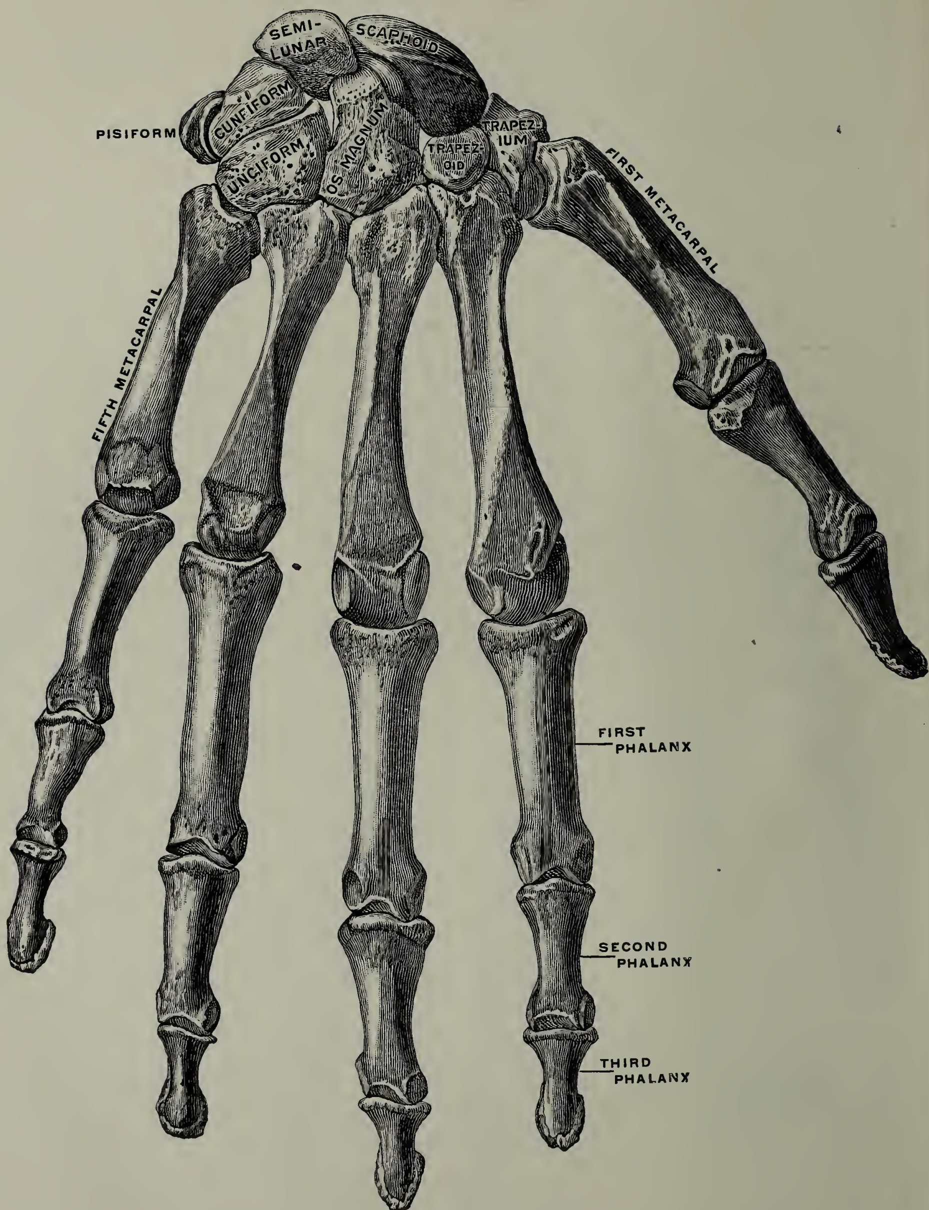


Fig. 76.—The bones of the right hand, dorsal aspect. (Spaltcholz.)

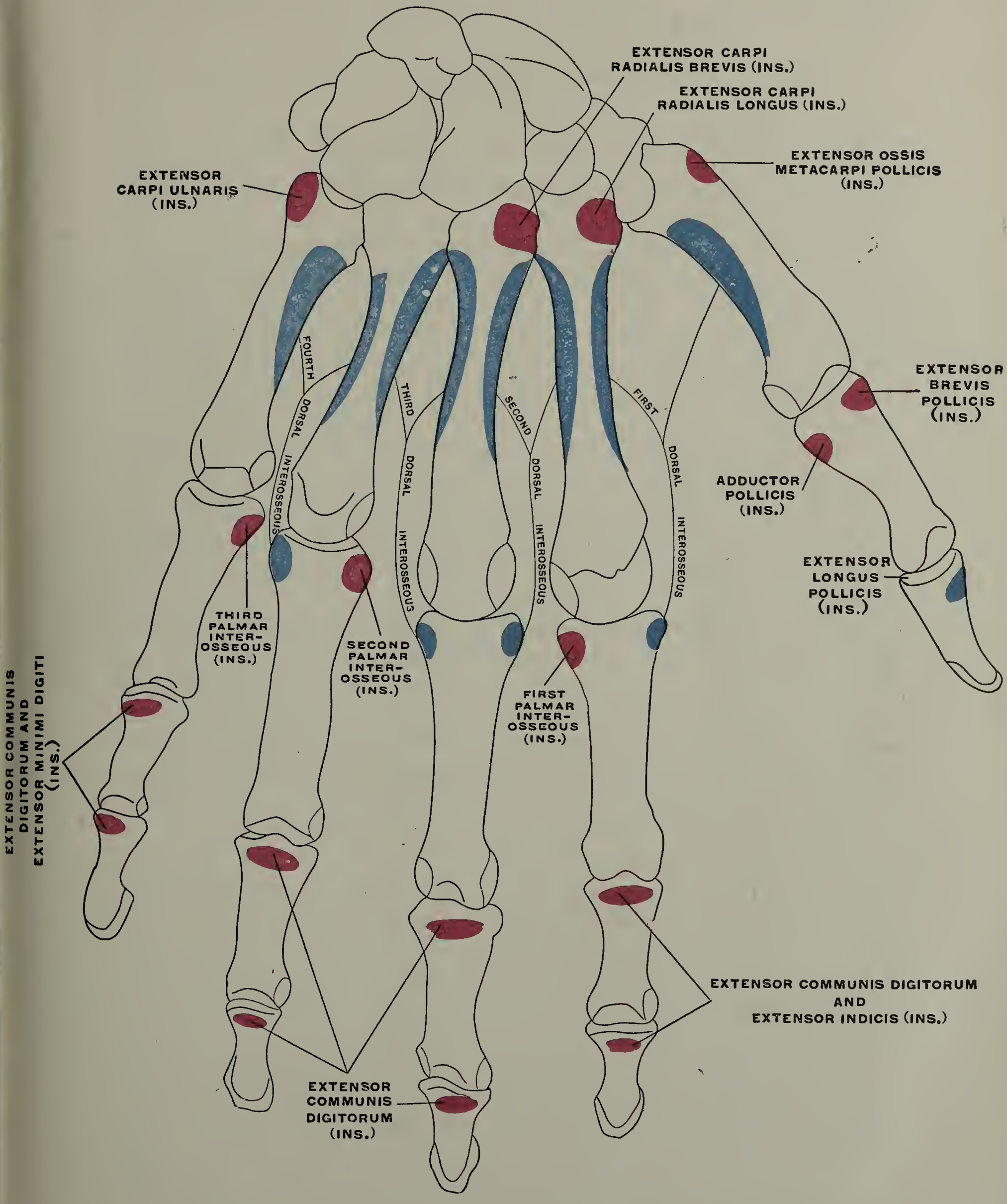


Fig. 77.—Areas of muscular attachment on the dorsal surface of the bones of the hand. Where the areas of origin and insertion are both presented, they are in the same color. INS., insertion. (Gerrish.)

digitorum muscle. On the middle two-fourths of the anterior surface of the shaft is the flexor longus pollicis muscle. On the lower fourth the pronator quadratus muscle is attached.

An oblique line on the dorsal surface with that on the front bounds an external surface to which the supinator muscle is attached. Midway on the external surface is a rough impression for the pronator teres muscle. The dorsal surface in the middle third gives origin to the extensor ossis metacarpi pollicis and the extensor brevis pollicis muscles.

The lower extremity is much larger than the upper and is somewhat quadrilateral in form. Inferiorly is a cartilage-covered surface with which two carpal bones, the scaphoid and semilunar, articulate. On the inner surface is the sigmoid cavity for the articulation with the head of the ulna. The external surface is prolonged downward into the styloid process, to which is attached the brachioradialis muscle.

When the hand is supine, the radius and ulna are parallel. During pronation the radius crosses over the ulna.

Ossification.—The lower extremity of the radius and ulna ossifies about the twentieth year. The upper extremity of the ulna matures about the sixteenth year, while that of the radius occurs about the eighteenth year.

Carpal and Metacarpal Bones.—The *bones of the hand* consist of eight carpal, five metacarpal, and fourteen phalanges. The carpal bones are arranged in two rows, named from the radial side inward, scaphoid, semilunar, cuneiform, and pisiform in the upper row, trapezium, trapezoid, os magnum, and unciform in the lower row. The carpus, placed in line with the forearm, forms a transverse arch which receives the flexor tendons of the hand, and numerous blood-vessels, and nerves.

Articulating with the lower row are five metacarpal bones, numbered from the radial side inward, the first being that of the thumb.

The metacarpal bone of the thumb is much the heaviest of the five. It is placed at an acute angle with that of the first finger. Greater mobility at its articulation with the carpus, and with the proximal phalanx of the thumb is obtained by this arrangement. The hand is thus rendered a prehensile organ.

The Phalanges.—Each finger has three long bones, the upper of which articulates with the corresponding metacarpal bone. The *ungual*, or terminal phalanx, bears the nail. The thumb has two phalanges, larger and heavier than those of the fingers. The proximal phalanx articulates with the first metacarpal. The distal phalanx bears the nail.

The articulations between the metacarpal bones and their corresponding phalanges allow abduction and adduction from and to the middle of the index finger.

Many muscles are attached to the bone of the hand. The flexors on the palmar, and the extensors on the dorsal surfaces. (Figs. 74–77.)

Ossification.—This is completed about the twentieth year.

THE BONES OF THE LOWER EXTREMITY.

The skeleton of the lower extremity consists of the bones of the hip, thigh, leg and foot. A sesamoid bone, the patella, is included.

The Os Innominatum.—The hip-bone, or os innominatum, is an irregularly shaped bone, having more resemblance to the blade of a ship's propeller than to anything else. It is expanded above and below, but narrower in the middle, where the deep socket for its articulation with the femur is seen. This socket, the *acetabulum*, is cup-like, and in youth shows the epiphyseal lines separating the three parts of which it is made. To the rough, uneven rim is attached a band of fibro-cartilage, the *cotyloid* ligament, which contracts the circumference of the cavity, as well as deepens it. The cavity is covered with cartilage, except for a mass of fat at the bottom, and the rough impression for the ligamentum teres muscle. The lower part of the rim is incomplete, forming the cotyloid notch, which is bridged over by the transverse ligament, forming the cotyloid foramen. The expanded upper part of the os innominatum forms the "false pelvis," a part of the wall of the abdomen, while the lower part forms the front and side walls of the "true pelvis."

The weight of the trunk, head, and upper extremities is transmitted to the lower extremities through the hip-bones. The three parts of the bone are the ilium, ischium, and os pubis, separate in early life, but united in adult years. These will be considered in turn as more convenient to describe and more easily comprehended than the bone as a whole.

The Ilium.—The ilium presents a broad, flat, and triangular appearance with a sinuously curved upper border, narrowing to the lower part which occupies nearly two-fifths of the cavity of the acetabulum. The upper border or crest is subcutaneous, with two prominent processes at the ends, that in front being the *anterior-superior spine*, giving attachment to Poupart's ligament, while just below this the sartorius and tensor fascia lata muscles are attached. The crest ends posteriorly in the *posterior-superior spine*, which gives attachment to a ligament of the sacro-iliac joint.

The crest is thick enough to be divided into three lips; inner, middle, and outer. To the inner lip the transversalis muscle is attached on the anterior three-fourths, and the quadratus lumborum and erector spinæ muscles on the rest. To the middle lip the obliquus

internus abdominis muscle, on the anterior two-thirds. To the anterior half of the outer lip, the obliquus externus abdominis, with the latissimus dorsi, and the gluteus maximus muscles on the posterior half.

Below the anterior-superior spine is a notch, which ends in the *anterior-inferior spine,* to which is attached the rectus femoris muscle and the ilio-femoral band of the hip-joint. Below this spine is a broad shallow groove over which the tendon of the ilio-psoas muscle passes on its way to its insertion on the femur.

On the internal or ventral surface of the ilium is a fossa, the *iliac fossa,* giving attachment to the iliacus muscle. Behind this is an articular surface, corresponding to the same-shaped surface on the sacrum, the *auricular* surface, for articulation with each other. A rough surface above this provides for the attachment of the posterior ligaments of the joint. The iliac fossa is bounded below by a slight ridge, called the ilio-pectinal line, which marks the top of the true pelvis. To this line is attached the pectineus muscle. Below the posterior-inferior spine, on the ventral surface, is the space occupied by the pyriformis.

The posterior surface or dorsum of the ilium presents three lines, the superior, middle, and inferior gluteal lines. Above the superior line is the gluteus maximus muscle; between the superior and middle lines is attached the gluteus medius muscle; between the middle and inferior lines is the gluteus minimus muscle. Between the inferior line and the edge of the acetabulum anteriorly, is the attachment of the reflected tendon of the rectus femoris muscle.

The Ischium.—The ischium is the lower and posterior part of the hip-bone, and forms about two-fifths of the acetabulum. It presents a heavy, thick tuberosity, a ramus, and a spine. The tuberosity is at the lowest part, supporting the weight of the body when sitting in a correct position. It gives attachment to the semimembranosus, the semitendinosus, the biceps femoris, the adductor magnus, the gemellus inferior and the quadratus femoris muscles. From the tuberosity the ramus ascends to join the ramus of the os pubis, anteriorly. To it is attached the adductor magnus, the obturator externus and the obturator internus muscles. On the front wall of the true pelvis is a large foramen, the obturator or thyroid foramen, which in life is covered by the obturator membrane. From this and the edges around on the inner surface arises the obturator internus muscle. Above the tuberosity, posteriorly, is the spine, with a small notch (lesser sacro-sciatic) below and a large notch (greater sacro-sciatic) above. In life, ligaments convert these into foramina. Through the greater sacro-sciatic foramen, passes the pyriformis muscle, various small vessels and nerves, in addition to the great sciatic nerve. The lesser sacro-sciatic fora-

men transmits the tendon of the obturator internus. To the spine is attached the gemellus superior.

The Os Pubis.—The os pubis forms the anterior part of the true pelvis, and is composed of three parts, the body, the horizontal and the descending rami. The body is quadrilateral and in the lower front part gives attachment to the adductors longus, brevis and gracilis, and a part of the magnus muscles. On its upper border is the spine to which Poupart's ligament and the outer pillar of the external abdominal ring are attached. Along the upper border, internal to the spine is the crest, to which is attached the rectus abdominis, the pyramidalis muscles and the conjoined tendon of the obliquus internus and transversalis muscles. On the inner side of the body is a rough articular surface for its articulation with the fellow of the opposite side. The body forms one-fifth of the acetabulum. The descending ramus joins the ramus of the ischium and gives attachment to the adductor magnus muscle. The horizontal ramus extends outward from the body to the ilium.

The Pelvis.—The cavity of the pelvis is shallow in front and deeper behind. The opening at the top is called the inlet, while that below is the outlet. In the erect position of the body the pelvis is tilted so the plane of the inlet is at an angle of from 50 to 60 degrees with the horizontal, and that of the outlet at an angle of about 15 degrees. The weight of the body is transmitted from the sacro-iliac synchondrosis to the acetabulum when in a standing position, and to the tuberosities of the ischium when in a sitting position. To thus receive and transmit the weight there are very strong ridges of bone between these parts of the hip bone, these ridges being strengthened and connected together anteriorly by counter arches which meet at the symphysis pubis. The expanded upper part of the pelvic girdle helps to support the abdominal viscera, and to furnish attachment to many muscles forming the abdominal wall. The large surface, external and internal, gives opportunity for many muscles, with admirable leverage, to connect the trunk and lower extremities. The bones of the true pelvis contain and protect the pelvic viscera, which are in intimate relation with those of the abdomen. The true pelvis in the two sexes differs in size and form. In the female the bones are smoother and lighter, as the muscles are usually exercised less vigorously. The cavity is broader, more capacious and less deep. About puberty, the female characteristics become marked, but prior to that the pelvis is undifferentiated, and the narrow and deep male type prevails. It is noticeable that the "athletic woman" is narrow in the hips and pelvis, retaining the characteristics of the pre-pubertal pelvis.

Ossification.—The parts of the os innominata unite between the twentieth and twenty-fifth years.

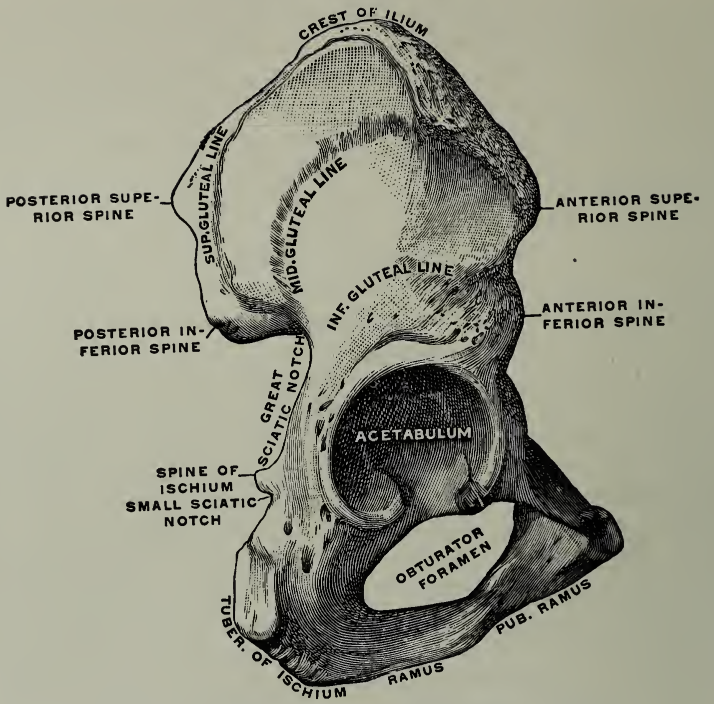


Fig. 78.—The right hip-bone, outer surface. (Testut.)

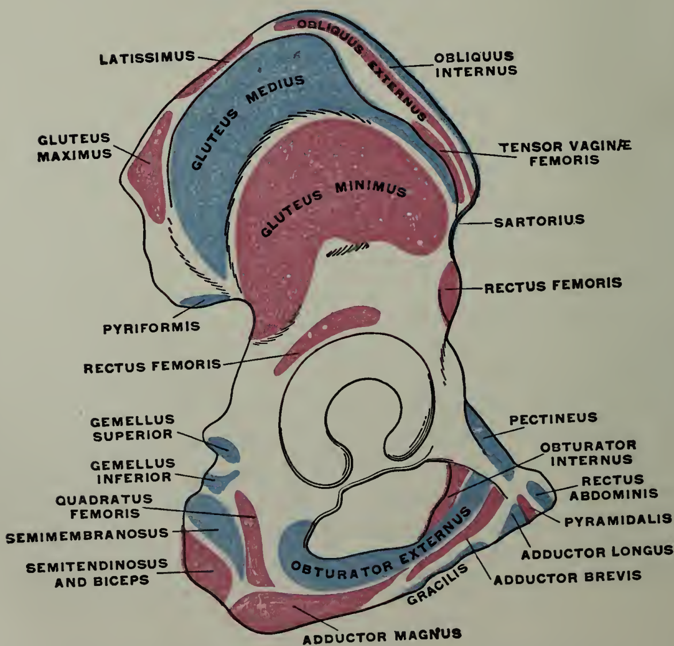


Fig. 79.—Areas of muscular attachment, outer surface of right hip-bone. (Testut.)

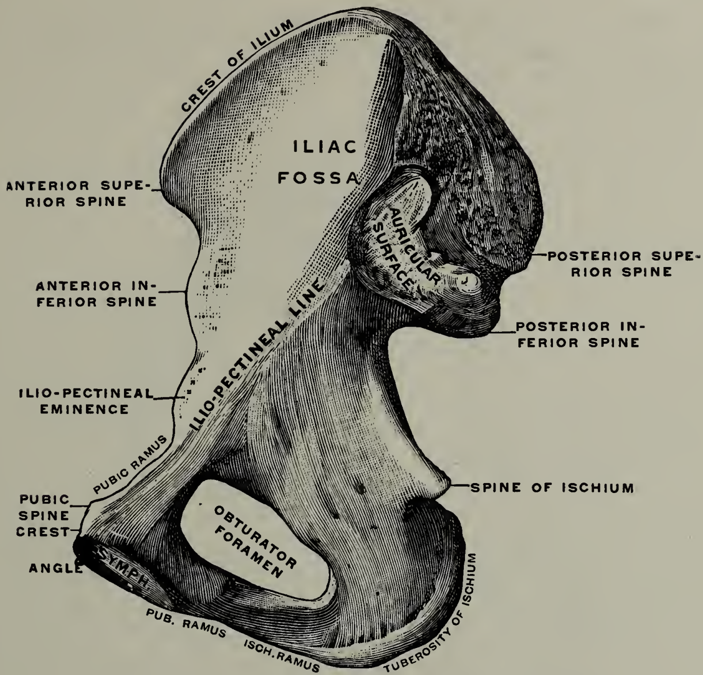


FIG. 80.—The right hip-bone, inner surface. (Testut.)

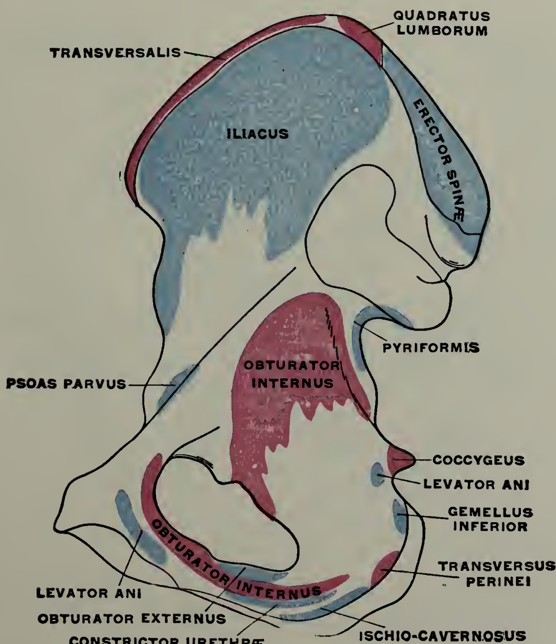


FIG. 81.—Areas of muscular attachment, inner surface of right hip-bone (Testut.)

The Femur.—The femur, the longest bone of the body, extends between the hip-bone and the tibia, articulating with both. It has a shaft and two extremities.

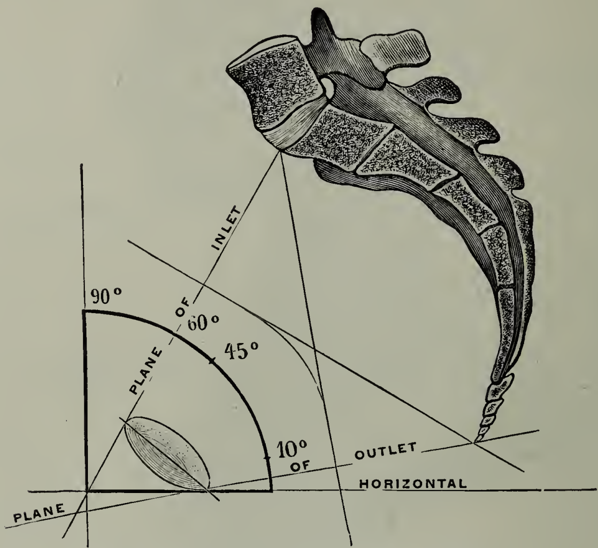


Fig. 82.—The planes of the pelvis. (Testut.)

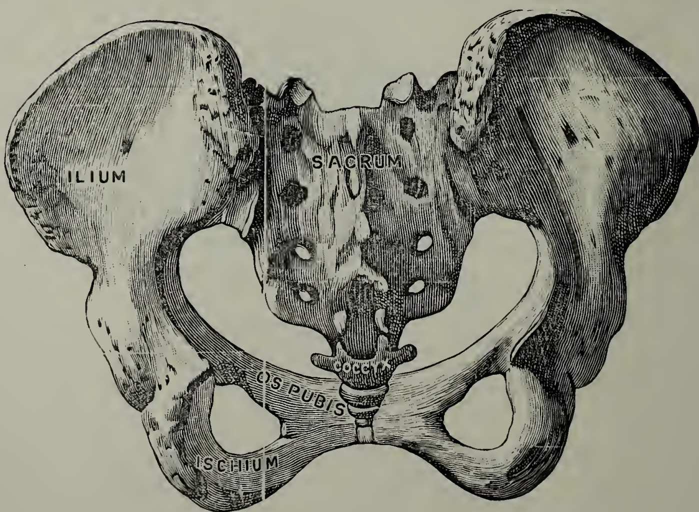


Fig. 83.—The female pelvis, rear view. (Testut.)

The *upper extremity* presents a head, neck, and two trochanters, great and small. The *head,* which articulates with the acetabulum,

is covered with cartilage in the recent state, and in shape is more than a hemisphere. Below and behind the center is a small depression for the ligamentum teres, by which the femur is held in the acetabulum. The *neck* joins the head to the shaft, and is directed outward, downward, and slightly backward, forming an angle of about 125 degrees with the shaft. At the junction of the neck and shaft are two projections, a large one externally, the great trochanter, and a small one, the small trochanter. This is pyramidal in shape, presenting from the inner and dorsal aspects. The great trochanter is a heavy, quadrilateral process continuous with the outer surface of the shaft. Its upper surface is on a level with the highest part of the neck. By this relation, the location of the hip-joint may be determined. From the top of the great trochanter to the small one, run rough lines, that on the front, the anterior intertrochanteric, that on the back, the posterior intertrochanteric line. The anterior line limits the neck in front and gives attachment to the capsular ligament. This line is continued around the bone as the spiral line, and joins the *linea aspera.* The vastus internus muscle is attached to it. On the back of the trochanter is a rough vertical line, the gluteal ridge, to which the gluteus maximus muscle is attached. The quadratus femoris muscle is inserted near by. Externally on the trochanter are the attachments of the gluteus medius and minimus and the vastus externus muscles.

Just internal to the upper part of the trochanter is a deep fossa into which the finger fits snugly, and so named the *digital fossa,* on the floor of which is the insertion of the obturator externus muscle. Above, and in front, the gemelli, the obturator internus, and the pyriformis muscles are attached. The small trochanter receives the tendon of the ilio-psoas muscle.

The *shaft* of the femur is nearly cylindrical, but with a flattened front and a prominent ridge behind, the linea aspera. It increases in size at the lower end. The front and sides of the shaft give attachment to the three vasti muscles, the internus, externus, and intermedius.

The *linea aspera,* formed by the joining of the spiral line and the gluteal ridge is thick and heavy in the middle third. It then divides into the internal and external condylar ridges, by which it continues to the condyles. The area enclosed by these ridges is the upper part of the popliteal space.

To the *linea aspera* are attached the adductors magnus, longus, and brevis, the pectineus, the short head of the biceps femoris, the externus and internus vasti muscles.

The *lower extremity* of the femur is much expanded, and has two large condyles, internal and external. Behind they are separated by the intercondyloid notch, but in front the trochlear surface for the patella unites them. If the femur is held vertically, the internal

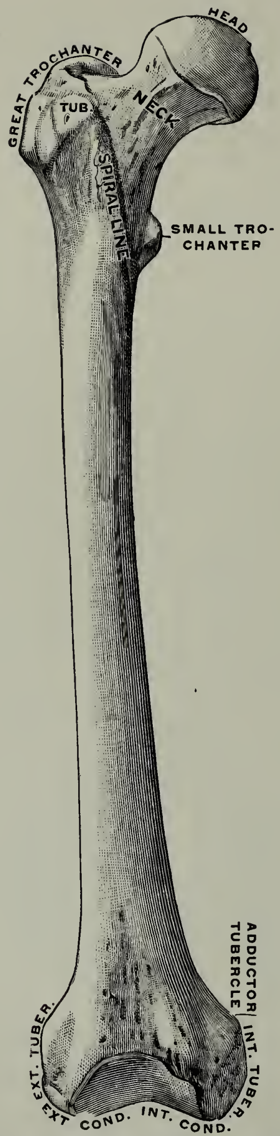


FIG. 84.—The right femur, front view. (Testut.)

FIG. 85.—Areas of muscular attachment, ventral surface of right femur. (Gerrish.)

condyle is apparently longer, but with the bone in position as in life, the lower edges are in line with each other and with the articular surface of the tibia. On the lateral surface of each condyle is a rough prominence, the tuberosity, which gives attachment to the ligaments of the knee-joint.

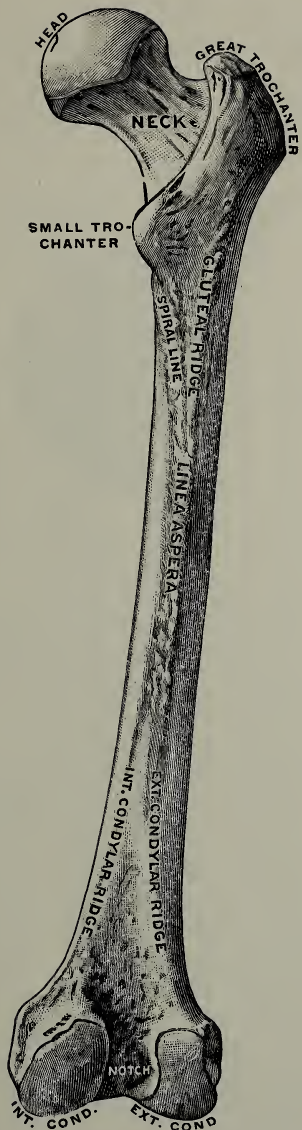


Fig. 86.—The right femur, rear view. (Testut.)

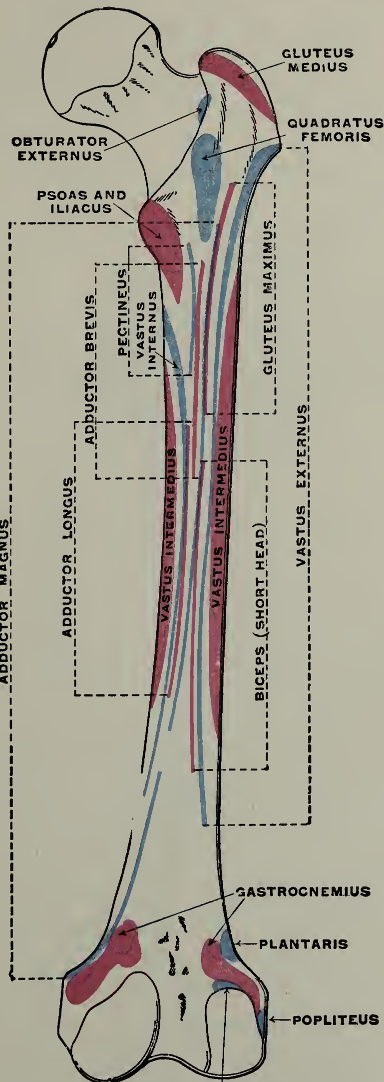


Fig. 87.—Areas of muscular attachment, dorsal aspect of right femur. (Gerrish.)

Above the posterior aspects of the condyles the two heads of the gastrocnemius muscle are attached; from the outer tuberosity the popliteus muscle and above that, the plantaris muscle.

Ossification.—The lower end of the femur unites with the shaft about the twentieth year. The upper end precedes it.

The Patella.—The patella on the front of the knee-joint is a small, flattish, sesamoid bone, with an articular surface dorsally and a rougher surface anteriorly. It articulates with the trochlear surface of the femur and takes part in the complicated knee-joint. Anatomists differ as to whether it should be considered as contained within the tendon of the quadriceps extensor cruris muscle or as giving insertion to it.

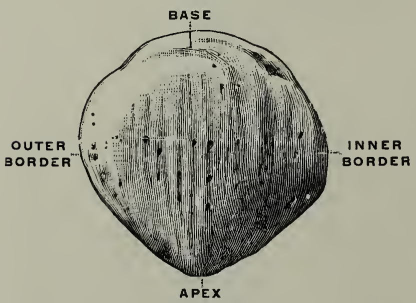


Fig. 88.—The right patella, ventral surface. (Testut.)

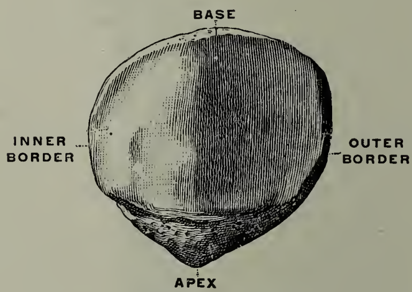


Fig. 89.—The right patella, dorsal surface. (Testut.)

The Tibia.—The tibia is the larger and heavier of the two bones of the leg, and presents a shaft and two extremities, the upper of which takes part in the knee-joint, and the lower in that of the ankle-joint.

The *upper extremity* is thick and heavy, with a tuberosity on each side. On the upper articular surface of these are depressions for the reception of the condyles of the femur. Projecting upward between these depressions is a spine, with a double peak, while behind this is a notch, the popliteal notch. With the area immediately below this, and that on the lower part of the femur, the diamond-shaped popliteal space is formed. The lower part of the tuberosities in front is marked by a prominent elevation, the tubercle of the tibia, to which the tendon of the quadriceps extensor cruris muscle is attached. In kneeling the body rests upon the tubercle. On the outer tuberosity, a little to the rear, is an articular surface for the head of the fibula. On the inner tuberosity is seen a groove in which the tendon of the semimembranosus muscle is inserted.

The *shaft* of the tibia gradually tapers from the tuberosities downward, and is again expanded at the lower end. Just below the inner tuberosity on the lateral aspect of the shaft is the common attachment of the sartorius, gracilis, and semitendinosus muscles. The internal surface, below these muscular attachments, is subcutaneous. The external surface presents a grooved area for the attachment of the tibialis anterior muscle on the upper two-thirds. On the posterior surface, from the articular facet for the head of the fibula,

an oblique line passes downward and inward to nearly the middle of the shaft. This gives attachment to the soleus muscle while on the triangular surface above the popliteus muscle is attached. Below this line the space is divided between the tibialis posterior

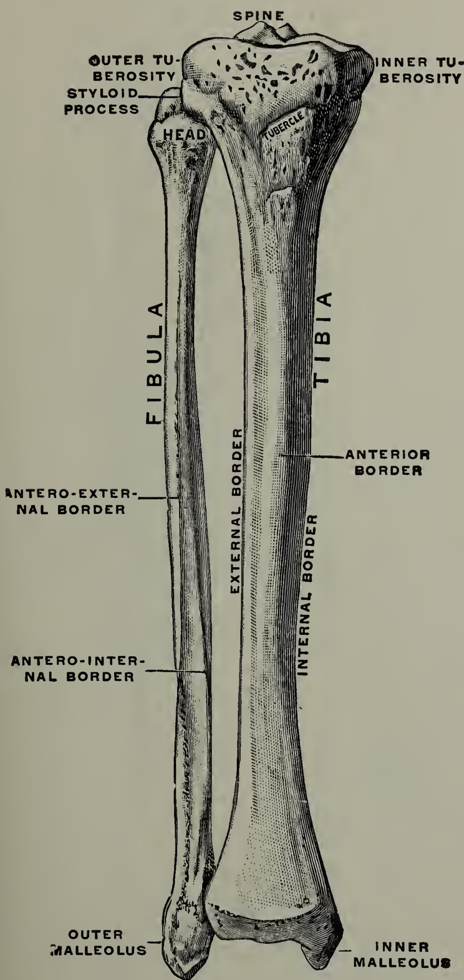


Fig. 90.—The right tibia and fibula in their normal relations, front view. (Modified from Testut.)

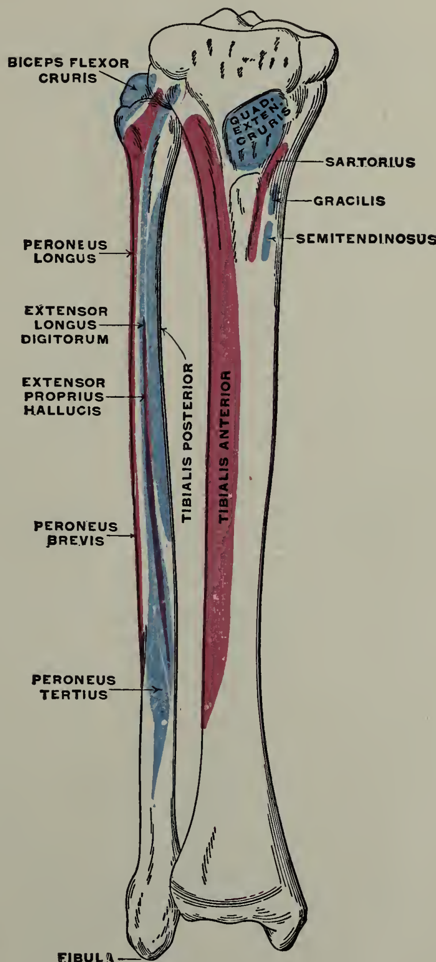


Fig. 91.—Areas of muscular attachment, anterior aspect of the tibia and fibula. (Gerrish.)

muscle on the outer side and the flexor longus digitorum muscle on the inner side.

Of the *borders,* the external gives attachment to the interosseous membrane, and the anterior is noticeable for its sharp edge, "the

shin," which is subcutaneous, serving as a sensitive outpost. The lower extremity of the tibia is expanded on the inner aspect into the *internal malleolus,* which enters into the formation of the ankle-

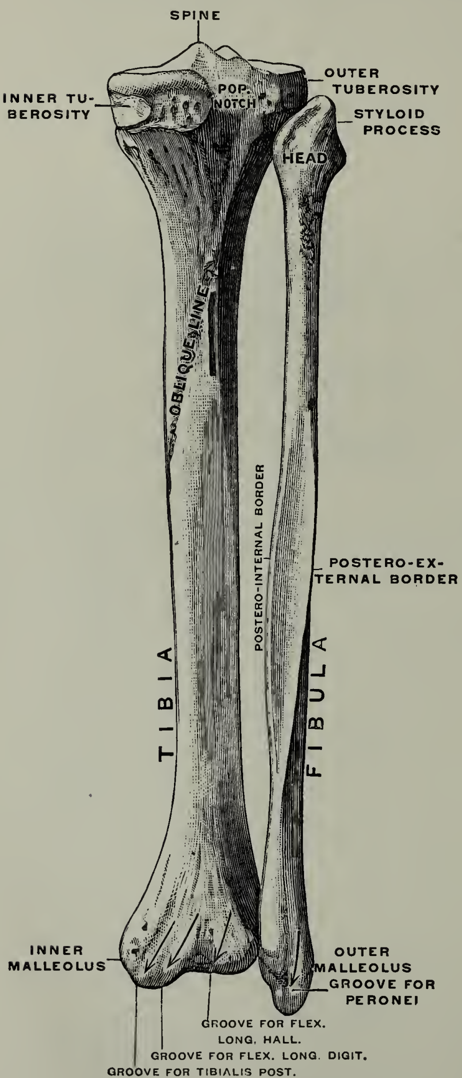


FIG. 92.—The right tibia and fibula in their normal relations, rear view. (Testut.)

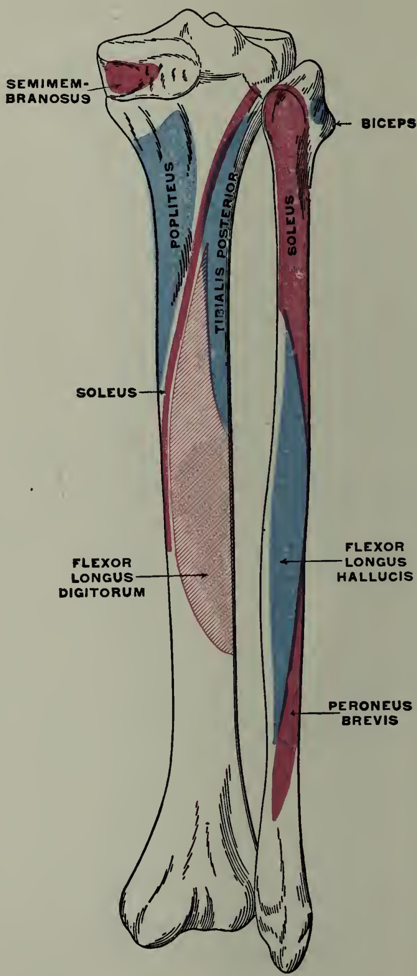


FIG. 93.—Areas of muscular attachment, posterior aspect of the tibia and fibula. (Gerrish.)

joint. On the opposite side is the surface for articulation with the fibula. On the under surface is a broad area for articulation with

the astragalus. Grooves for the passage of tendons are seen on the back.

Ossification.—This is completed at the lower end about the eighteenth year, and at the upper end two years later.

The Fibula.—The fibula or the outer bone of the leg is very slender, with the surfaces changing in direction so frequently it is very difficult to distinguish and describe borders or surfaces. The upper extremity or head has a conical process above, the *styloid process,* to which the tendon of the biceps femoris muscle is attached. A facet provides for the articulation with the tibia. The shaft gives attachment to the anterior group of muscles that flex the foot, namely, extensor longus digitorum, proprius hallucis, and peroneus tertius; the external or foot pronator group, peroneus longus and brevis; the posterior or foot extensor group, flexor longus hallucis and soleus; and the supinator muscle, tibialis posterior. The lower extremity presents the external malleolus, a process that extends downward beyond that on the inner side, to take part in the ankle-joint. A facet on the inner side articulates with the tibia, and another, somewhat to the front, with the astragalus.

Ossification.—In the lower part this is completed about the twentieth year. The upper part about the twenty-fifth year.

The Bones of the Foot.—The bones of the foot have an arrangement similar to that in the hand, but with certain essential differences due to the differences in function. While the hand is a prehensile organ, the foot is an organ for support and locomotion.

Seven tarsal, five metatarsal and fourteen phalanges make up the total. The description of the tarsal bones follows.

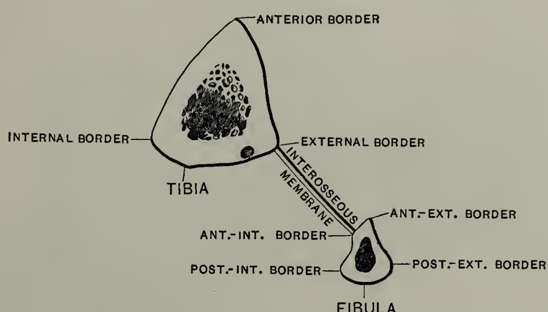


Fig. 94.—Horizontal section of the bones of the leg at the junction of the upper and middle thirds, showing their borders and surfaces and the relations of the interosseous membrane. (Testut.)

The Astragalus or Talus.—The astragalus unites with the tibia and fibula to form the ankle-joint. It is joined to the calcaneum behind, and to the scaphoid in front. The weight of the body is transmitted to the astragalus through the tibia, so the bone is of necessity strong and heavily built.

The Calcaneum.—The calcaneum or heel bone is the largest of the tarsal bones and transmits the weight of the body to the ground. The hind part of the bone is placed lower than the front, and on the posterior surface gives attachment to the tendo Achillis, the combined tendon of the gastrocnemius, soleus and plantaris muscles. Jutting out from the inner side is a shelf-like process the susten-

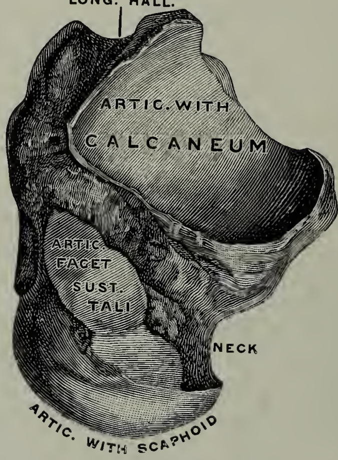


Fig. 95.—Right astragalus, under surface. (Spalteholz.)

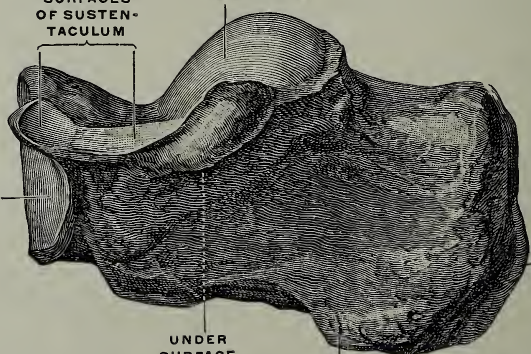


Fig. 96.—Right calcaneum, internal surface. (Spalteholz.)

taculum tali, on which the astragalus rests in its articulation with the calcaneum. On the anterior aspect is a facet for articulation with the cuboid.

The Cuboid.—The cuboid is in front of the calcaneum and on the outer side of the foot. It articulates with the fourth and fifth metatarsals, as well as with the calcaneum. On the under surface

is a deep groove through which passes the tendon of the peroneus longus muscle.

The Scaphoid or Navicular.—The scaphoid is placed on the inner side in front of the astragalus. It articulates with the astragalus, the internal, middle, and external cuneiform bones, and occasionally with the cuboid. It has a tubercle on the inner surface which serves to locate the medio-tarsal-joint and gives attachment to the tibialis posterior muscle.

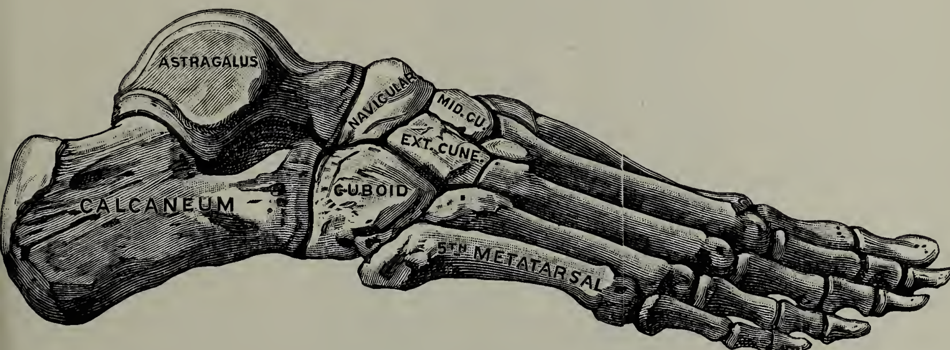


Fig. 97.—The bones of the right foot, viewed from the outer side. (Testut.)

The Cuneiform Bones.—Three cuneiform bones in front of the scaphoid are wedge-shaped, articulating with each other, with the scaphoid, the cuboid, and all the metatarsals except the fifth.

The tarsal bones are placed at right angles with the leg, thus providing for the upright position of man.

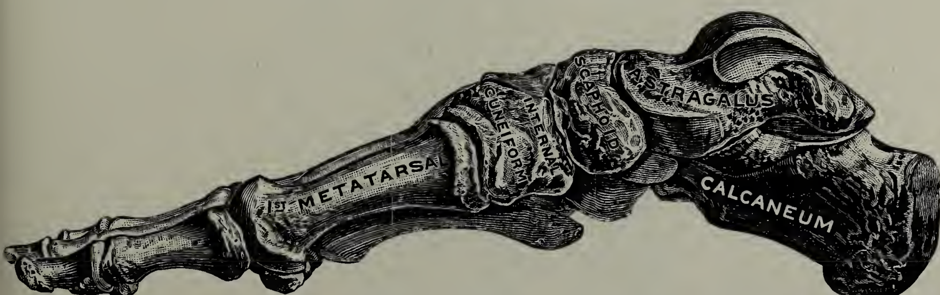


Fig. 98.—The bones of the right foot, viewed from the inner side. (Spalteholz.)

The Metatarsal Bones.—The five metatarsal bones are placed side by side in front of the tarsus. The bases of the first three articulate with the three cuneiform bones. The fourth and fifth articulate with the cuboid. The heads of the five articulate with the first phalanx of the corresponding toes. That of the great toe is much heavier than the others, and is parallel, in position, with

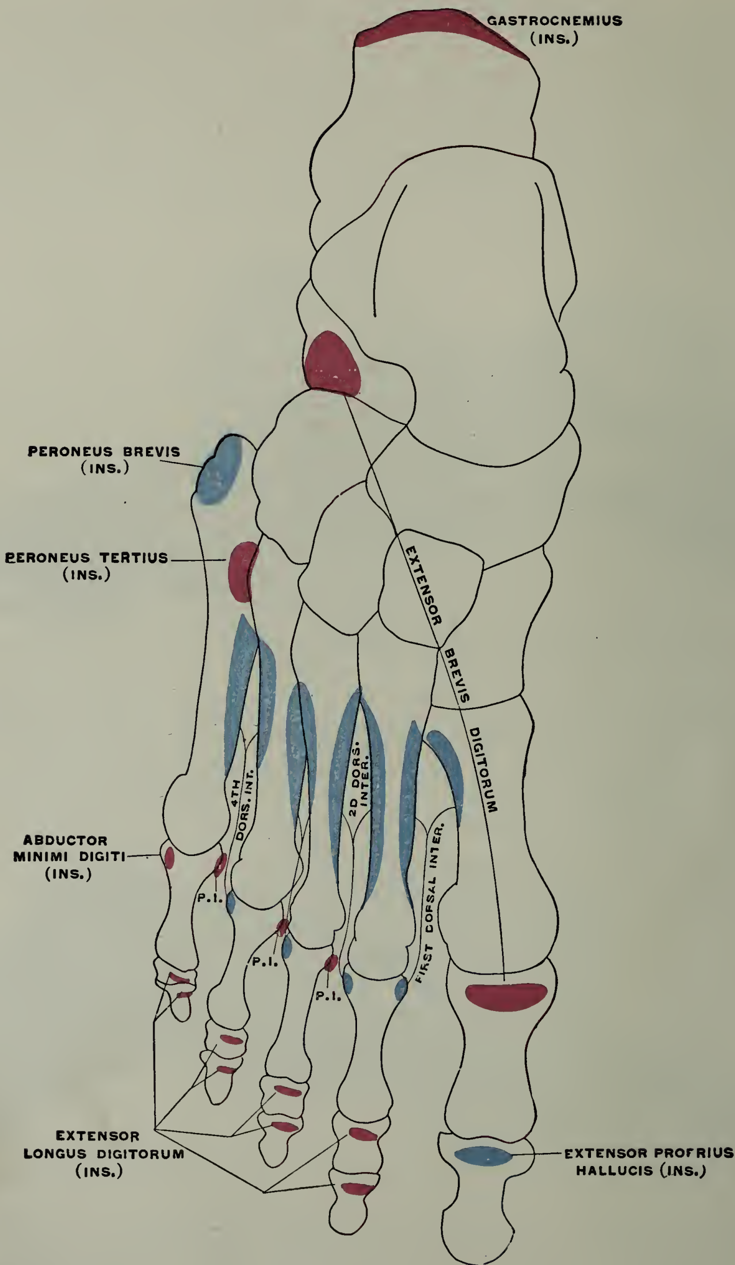


Fig. 99.—Areas of muscular attachment on the dorsal surface of the bones of the foot. Where the areas of origin and insertion are both presented they are in the same color. The third dorsal interosseous is not labeled. P.I., plantar interosseous insertion; INS., insertion. (Gerrish.)

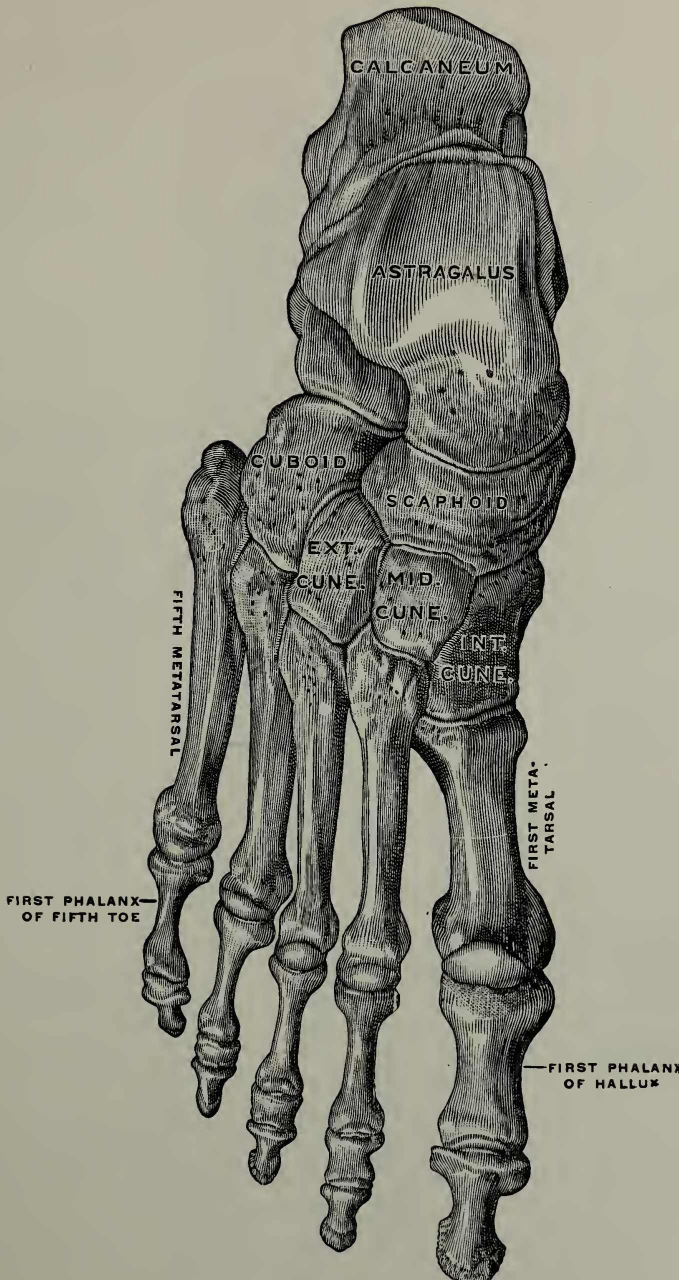


FIG. 100.—The bones of the right foot, viewed from above. (Albinus.)

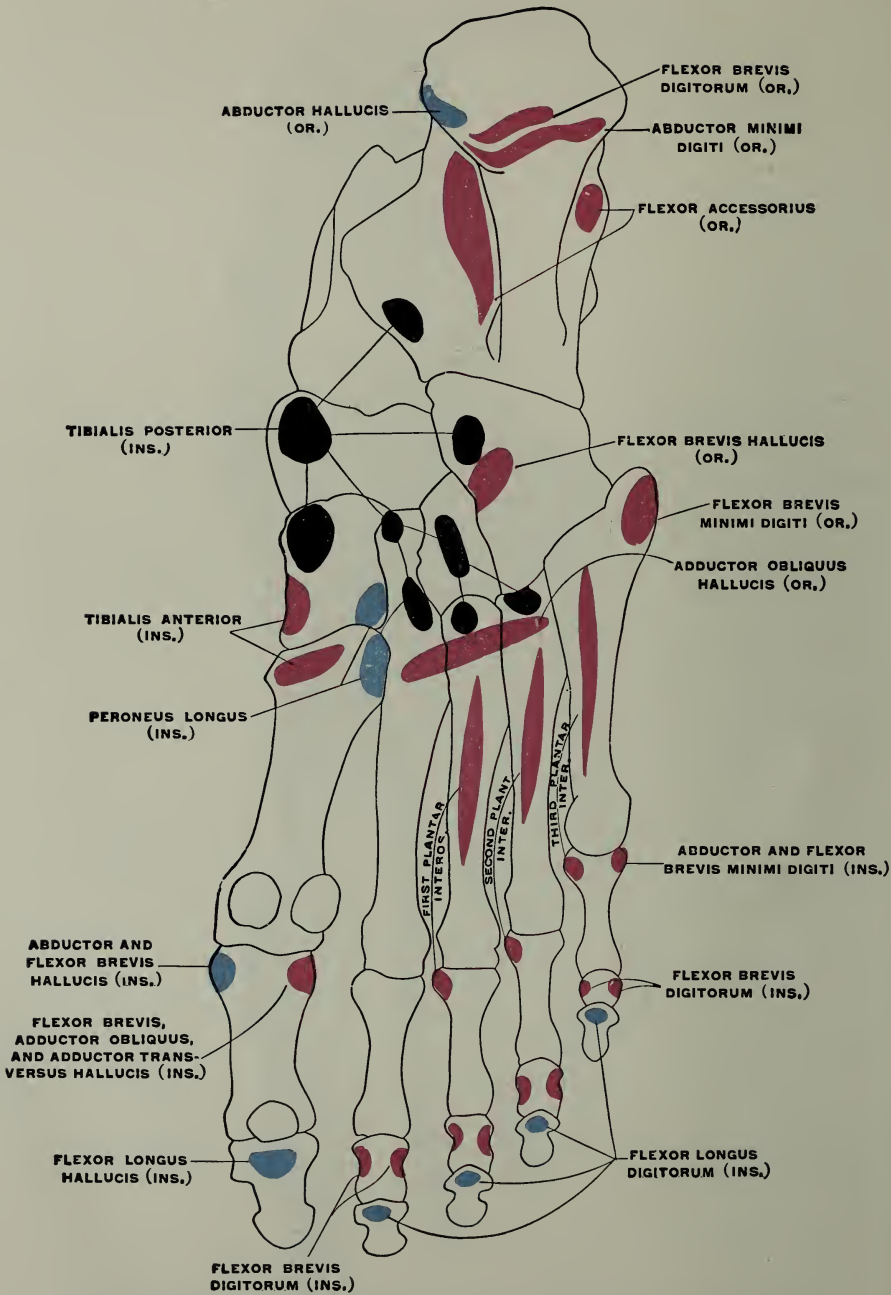


FIG. 101.—Areas of muscular attachment on the plantar surface of the bones of the foot. Where the areas of origin and insertion are both presented they are in the same color. OR., origin; INS., insertion. The insertion of the second and third tendons of the flexor brevis digitorum are not labeled. (Gerrish.)

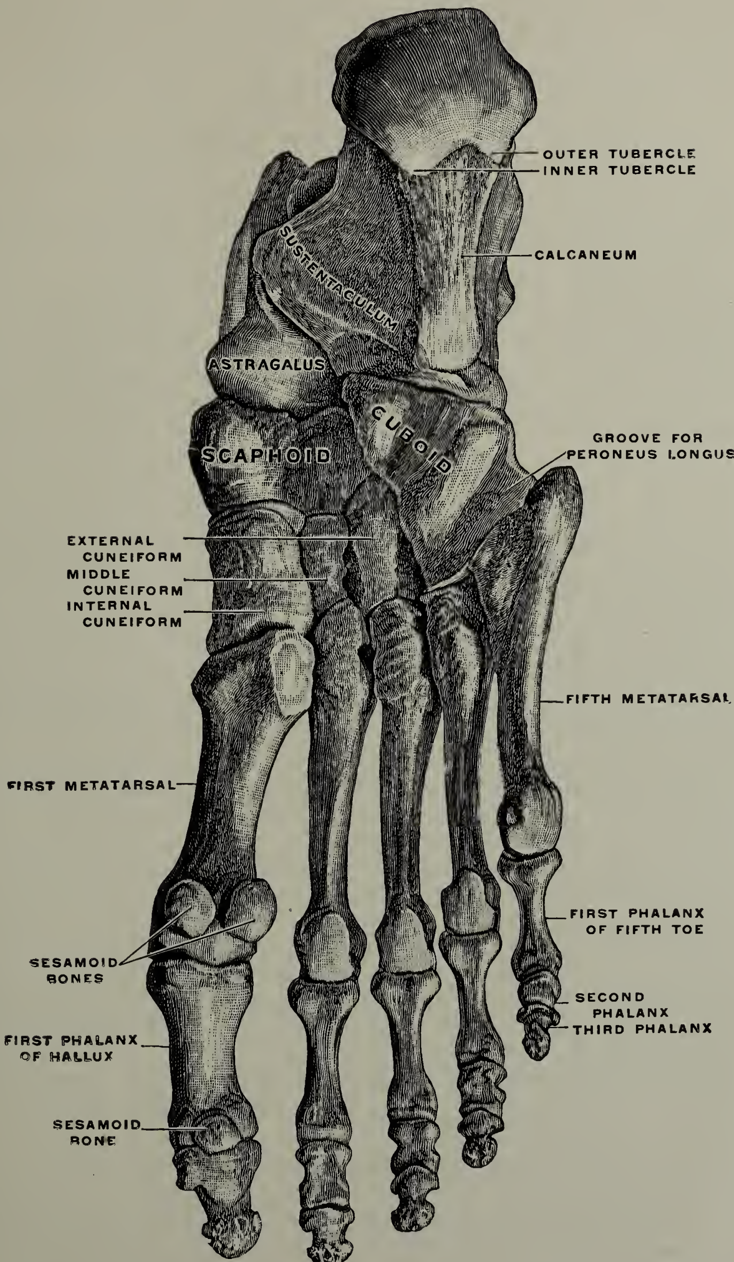


Fig. 102.—The bones of the right foot, viewed from below. (Spalteholz.)

the others. This contrasts with the position of the first metacarpal. Under the head of the first metatarsal bone are two small sesamoid bones. The fifth or the metatarsal of the little toe is the longest, with a prominent tubercle at its upper end. This tubercle is just in front of the outer part of the medio-tarsal joint.

The Phalanges.—The phalanges, two for the great toe and three for all the others, are similar to those of the hand, but much shorter, especially the terminal or ungual phalanges. Those of the first row articulate with the metatarsal bones, and with the second row of phalanges.

Many muscles find attachment to the bones of the foot. Those on the plantar surface serve as flexors of the toes and extensors of the ankle. Muscles attached on the dorsum extend the toes and flex the ankle. In addition, the pronators and supinators of the foot have their insertions on the tarsal or metatarsal bones. (Figs. 100–102.)

QUESTIONS.

How many bones to form the *cranium?* Why should there be that many?

Name the parts of a typical *vertebra.*

How are the *cervical* vertebræ distinguished?

How are the *thoracic* vertebræ distinguished?

Describe a typical *rib.*

Name the parts of the *scapula.*

Distinguish the right *humerus*, and place it so it will correspond with its position in the body.

What are the markings on the *radius?*

How many *carpal* bones are there? Why should there be so many bones in a hand?

What and where is the *patella?*

How is the *femur* directed when articulated?

Name the principal points of interest on the *ilium.*

What is the "*linea aspera?*"

What is the *tubercle of the tibia*, and what is attached thereto?

Find on yourself the principal bony landmarks, such as the olecranon process, the acromion, the tubercle of the scaphoid, the head of the fibula, the external occipital protuberance, the seventh cervical spine, the anterior, superior spinous process of the ileum.

Why is the first metacarpal bone placed at an acute angle with the first finger?

CHAPTER IV.

THE ARTICULATIONS.

At various places on the bones of the skeleton they are connected together. These unions are articulations, or joints.

Typical Joints.—Depending upon the amount of movement to take place, the surfaces on the bones vary in size and shape. Even where no movement is expected, the presence of a joint adds elasticity to the part.

If there is to be no movement, the two surfaces come close together, with only a cement substance between them, as in the *sutures* of the skull.

If much strength with slight movement is necessary, the bony surfaces are separated and united by plates of fibro-cartilage, as in the intervertebral disks between the bodies of the vertebra.

If, as in the joints between long bones, free movement is to occur, the articular surfaces are much expanded, with more or less space between them. This increases their strength very much. Hyaline cartilage covers such surfaces, to impart smoothness. They are enveloped in a continuous sheath of fibrous tissue, called a *capsule.* Inside this capsule is a lining of epithelial tissue, the *synovial membrane,* which secretes as a lubricating fluid, a thick, sticky, glairy material, called "synovia," which resembles the white of egg. Where there is more strain, bands of fibers, called "ligaments," are placed on the outside of the capsule.

Additional elements of joints are white fibrocartilage in several forms. In freely movable joints that are exposed to much concussion, the fibrocartilage is in the form of flat plates, placed between the bones. These are found between the clavicle and the sternum; the temporal bone and the mandible; in the wrist, and in the knee. They obliterate the space between the bones, increase the depth of sockets, act as buffers in lessening pressure and shock, and make gliding easier. As mentioned above, such plates are in joints having little motion, as between the bodies of the vertebræ. Triangular on cross-section, are the rings of this material placed on the edges of cavities to protect the bone and deepen sockets. At times, the bones are directly connected by fibrous bands passing between them, as the crucial ligaments and the ligamentum teres.

Periarticular structures include the small, closed, fibrous sacs, lined with synovial membrane, which we call "bursæ." These are placed between surfaces that are likely to be irritated by the friction

between moving parts, as a muscle over a rough bone, a muscle over a muscle, or skin over bone. With them may be classed the tendons of muscles passing over a joint, very close to it, which serve as accessory ligaments.

Classes of Joints.—Three classes of joints are recognized, according to the amount of motion permitted.

Synarthrodia.—These permit no motion. Among them are the sutures of the skull; those between the socket at the end of a rib which receives a cone of cartilage into it; and the temporary unions between the diaphysis and epiphysis of immature bone, which are held together by a layer of cartilage.

Amphiarthrodia.—These permit slight motion. The bony surfaces are close together, covered with cartilage, and held together by ligaments. The joint between the sacrum and ilium, that between the two pubic bones, and those between the vertebral bodies are in this group.

Diarthrodia.—These permit more or less free movement. These joints have articular cartilage over the joint surfaces, and are connected by ligaments lined with synovial membrane. Subdivisions of this class are determined by the kind of motion permitted. This is dependent upon the shape of the articulating surfaces, though the ligaments connecting the bones and the surrounding muscles limit the motion.

Kinds of Movement.—*Flexion and Extension.*—When a movement takes place about a transverse axis, giving a change in the extent of the angle between the bones, it is called *flexion* if the angle is reduced, and *extension* if the angle is increased. If an angular movement toward the middle line of the body, the middle of the second finger, or the second toe occurs, it is called *adduction.* If the movement is away from these centers, the movement is *abduction.*

Circumduction is a combination of the above four movements in one continuous movement, with the figure of a cone described in space, the apex at the joint and the base of the cone at the further extremity. This should not be confounded with rotation.

Rotation is the movement of a bone around a longitudinal axis, in which the figure described in space is a cylinder.

Gliding is a sliding of surfaces upon each other without any angular or rotary movement.

Classes of Diarthrodia.—*Arthrodia* or gliding joints allow a limited gliding between two nearly flat surfaces, as those of the articular processes of the vertebræ.

Ginglymus or hinge joints allow movements of flexion and extension about a transverse axis, as in the elbow- and knee-joints.

Condyloid joints allow abduction, adduction, flexion, extension and circumduction, but *not rotation.* An ovoid surface is received

into an elliptical cavity, thus preventing any turning. The metacarpophalangeal joints illustrate this kind of joint.

Reciprocal Reception.—A modification of condyloid joints, called either "saddle joints" or those of reciprocal reception have the surfaces reciprocally saddle-shaped, as in the carpo-metacarpal joint of the thumb. They allow all movements except rotation.

Enarthrodial, or *ball-and-socket joints,* such as those at the hip and shoulder, consist of a more or less spherical head received into a cup-shaped cavity. They allow free movement in every direction.

Pivot joints, those between a pivot and encircling ring, as in the articulation between the axis and atlas, and that between the upper parts of the radius and ulna, allow the movement of rotation only.

In describing the articulations, those not of particular interest to the student of hygiene will be given but brief consideration.

THE ARTICULATIONS OF THE VERTEBRAL COLUMN.

These include the joints between the bodies of the vertebræ, the articular processes, the laminæ, the spinous processes, and the transverse processes.

The *bodies* of the vertebræ are joined together by disks of fibrocartilage, which correspond in shape with the bodies. These disks are tough, elastic, and compressible, varying in thickness in different regions of the spine. In the center of the disk is a spherical mass of pulpy material, which is compressed by the layers of fibrocartilage, so it rebounds when the mass is cut across, and seems like a small ball or pivot. Around this mass the vertebra moves in every direction. The thickness of these disks varies, being thinnest in the cervical, and thickest in the lumbar region of the spine.

Passing down the front of the bodies and intervertebral disks is the anterior common ligament, beginning at the under surface of the occiput, as a narrow band, and widening as it descends until it reaches the sacrum. This ligament connects the front of the bodies of the vertebræ, and limits the movement of extension of the spine.

The posterior common ligament passes along the posterior surfaces of the bodies and disks, from the occiput to the coccyx, being broader above and narrower below. It connects the backs of the bodies, helps to form the lining of the vertebral canal, and limits flexion of the spine.

These intervertebral articulations are amphiarthrodial joints allowing slight movement in every direction with the fibrocartilages compressed when the rest of the spinal articulations are in movement.

The joints between the articular processes are gliding joints, with capsular ligaments, lined with synovial membrane. These ligaments are loosest in the cervical region, and tightest in the thoracic.

Connecting the laminæ are ligaments that are unusual in that

they contain elastic fibrous tissue. These are the *ligamenta subflava*, and besides causing the return of the surfaces to their normal

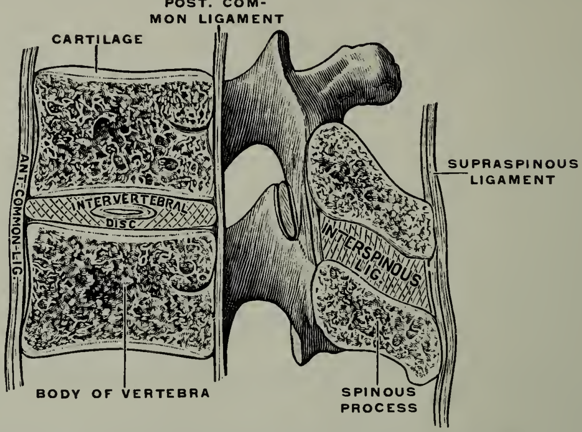


Fig. 103.—Two lumbar vertebræ in sagittal section. (Testut.)

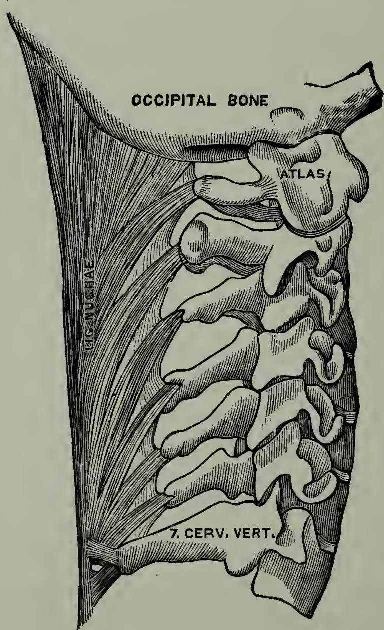


Fig. 104.—The ligamentum nuchæ, seen from the right side. (Henle.)

position after each movement, thus taking the place of muscles, they prevent the capsular ligaments from being pinched between the articular surfaces during such movement of the spine.

The tips of the spinous processes are connected by bands of fibers, called the supraspinous ligaments. In the cervical region, these are accentuated as the *ligamentum nuchæ,* or nape ligament. In quadrupeds this is very strong, as it supports the head, but it is much less marked in man. It consists of strong, fibrous tissue, intermixed with some elastic fibers. It gives attachment to several muscles. Ligaments pass from the under surface of one spine to the upper border of the spine below, and between the transverse processes.

Movements of the Spinal Column.—The spinal column is the axis of the skeleton. Every movement of the body influences its position, and the pull of the muscles acting upon it. Further, it must resist jar and provide strength with mobility. The motion between any two vertebræ is slight, but the sum of the movements of the twenty-six vertebræ amounts to a relatively large range. Around the pulpy ball in the center of the intervertebral fibrocartilage, the movement is in every direction, as of a ball-and-socket joint, but limited by the articular processes and the ligaments. Noting the direction in which the articular processes face, and remembering that gliding is their only possible movement, it is seen that in the cervical region the obliquity of the surfaces would allow some movement in practically all directions. In the dorsal region, side bending would be more possible. In the lumbar spine, the movements of flexion and extension would take place most readily, while rotation and side bending are extremely slight.

The overlapping spines in the thoracic region limit extension while the attached ribs prevent much movement laterally. This arrangement prevents much interference with the respiratory movements. The thick intervertebral disks in the lumbar region provide for a fairly free movement, and the small bodies in the cervical region allow a similar freedom there. The thick fibrocartilage disks absorb shock.

The spine is a flexible structure, already curved in two directions in the antero-posterior plane, and as Lovett has so well pointed out, it must be considered as a flexible curved rod, which cannot be bent laterally without accompanying torsion.

ARTICULATIONS IN THE UPPER CERVICAL REGION.

The condyles of the occiput articulate with the facets on the upper surface of the *atlas,* forming a condylar joint. Flexion, extension and side bending, but not rotation is possible. The articulation between the odontoid process of the axis, and the atlas provides for free rotation, and the movements of the head on the atlas and of the atlas on the axis are usually closely associated

and merged, amounting to a very free range, as though it were a ball-and-socket joint.

The *atlantoaxial articulation* differs from the typical articulations of the vertebral column. It consists of four joints: that between the front of the odontoid process of the axis, and the back of the anterior arch of the atlas; that between the back of the odontoid process and the front of the transverse ligament; those between the articular processes of the two vertebræ. Crossing from one lateral mass of the atlas to the other, the transverse ligament passes back of the odontoid process of the axis, keeping the process in contact with the back of the anterior arch of the atlas. This arrangement prevents undue pressure on the spinal cord. The process is constricted at this point, so making the union very firm. Joint cavities, lined with synovial membranes, are the anterior and posterior surfaces of the process. Between the front of the two bones, passes the anterior ligament, with the same arrangement connecting the posterior edges. The articular surfaces are surrounded by a capsular ligament.

The articulation between the atlas and the odontoid process is a *pivot joint,* allowing rotation of the atlas, carrying the head, around the axis. Flexion and extension to a slight degree are allowed at the articular joints.

ARTICULATIONS OF THE THORAX.

The anterior ends of the first seven ribs articulate with the facets on the sternum, and allow a slight hinge movement on the sagittal and obliquely vertical axis. The cartilages of the next three ribs are joined to that of the seventh and thus indirectly to the sternum.

Posteriorly, the heads of the ribs articulate with either the body of the corresponding thoracic vertebra, or with the bodies of two adjoining vertebræ and the intervertebral fibrocartilage. The tubercles of the ribs articulate with the facets on the transverse processes of the vertebræ. Capsular ligaments hold the bones together.

The movement at these joints is mostly rotation around an oblique axis upward or downward. The ribs are inclined obliquely downward. During the movement of inspiration, the inclination is lessened as the sternal ends of the ribs move forward-upward. This increases the antero-posterior diameter of the thorax. At the same time, the lateral diameter is increased by the lessening of the angle with the costal cartilages, in front, and by the elevation of the lateral part of the rib and the eversion of the lower border, behind. The first and second ribs, being flatter and with less obliquity than the others, are raised in inspiration, so increasing the vertical diam-

eter of the thorax. During expiration, by the relaxation of the muscles, the reverse action takes place (Fig. 105).

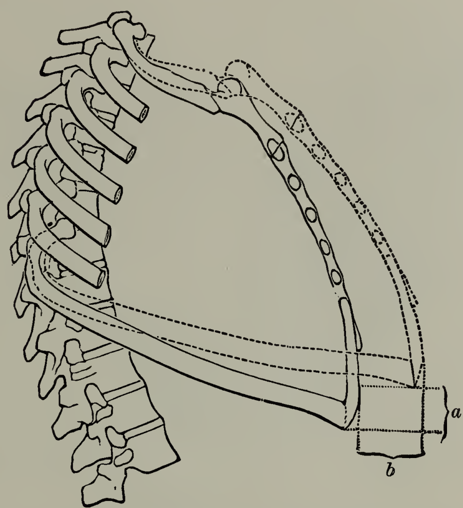


Fig. 105.—Diagram of the displacement of the ribs and sternum in inspiration: *a*, indicates the degree of upward movement; *b*, that of forward movement. (Testut.)

THE ARTICULATIONS OF THE UPPER EXTREMITY.

The upper extremity is attached to the main skeleton at only one place, the articulation between the clavicle and the sternum.

The Sterno-clavicular Articulation.—In the sterno-clavicular articulation, the two surfaces of bone, the facet on the manubrium and the end of the clavicle do not fit together accurately. To fill the space there is a plate of fibrocartilage interposed, with synovial cavities on each side of it. The surfaces glide upon each other as a rounded head moves in a shallow socket. This arrangement, while giving freedom, makes for easy displacement. To prevent upward displacement, a strong band of fibers, the *interclavicular* ligament, passes from the end of one clavicle to that of the other and dips down to the upper border of the sternum. Anterior and posterior sterno-clavicular bands guard the joint front and back, with additional fibers completing a capsule.

An accessory band of fibers, the *costo-clavicular* or *rhomboid* ligament, joins the lower surface of the clavicle to the front of the first rib. This aids in preventing upward displacement, as well as that in the backward direction.

The student should place one finger on the articulation and note the movements of the clavicle when raising, lowering, and carrying the arm forward and backward. The clavicle with the scapula

moves up and down, backward and forward, and in circumduction. On raising the arm a slight rotation occurs at this joint.

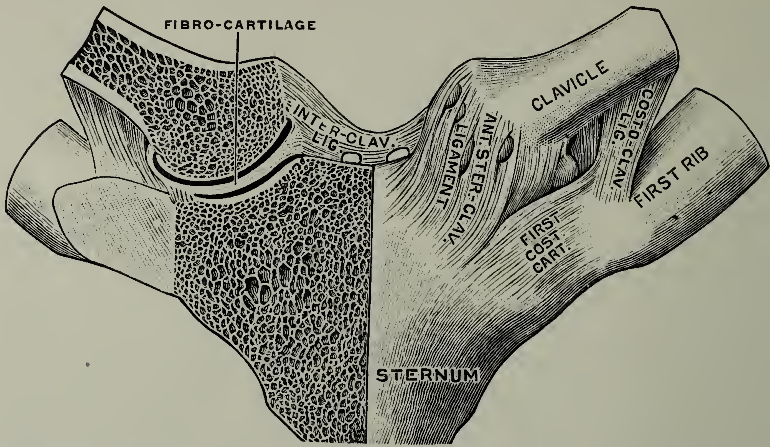


FIG. 106.—Sterno-costo-clavicular articulation, front view. The left half is seen in coronal section. (Testut.)

The Scapulo-clavicular Articulation.—The scapula is joined to the clavicle by a gliding joint between the acromial end of the clavicle and the acromion of the scapula. The capsular ligament surrounding it, allows only a small amount of movement.

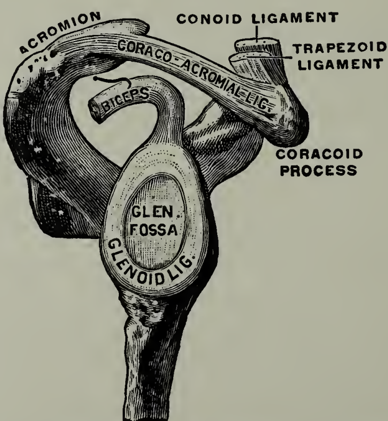


FIG. 107.—Glenoid fossa of right side. (Testut.)

A much stronger union is made between the coracoid process of the scapula and the under surface of the clavicle. From the root of the coracoid process, strong bands of fibers pass to the *conoid* tubercle of the clavicle. This is the conoid ligament by which the

scapula is said to hang from the clavicle. From the upper surface of the coracoid process the *trapezoid* ligament extends to the trapezoid ridge of the clavicle.

An additional union between the clavicle and scapula is made by the coraco-acromial ligament, passing between the coracoid process and the acromion, and forming an arch over the shoulder-joint. This protects the joint and holds off the deltoid muscle.

Movements of the acromio-clavicular joint are usually combined with those of the sterno-clavicular joint. The combination of turning the glenoid fossa upward or downward, with the elevation or depression of the clavicle, results in what is known as the rotation of the scapula. When the arm is raised, this rotation turns the glenoid fossa further upward and outward, carrying the lower angle outward. The reverse occurs in lowering the arm.

The scapula and clavicle move independently of the arm with an upward and forward movement, and a downward and backward movement. In these, the lower angle of the scapula does not move outward toward the axilla as in the movements associated with arm raising or lowering.

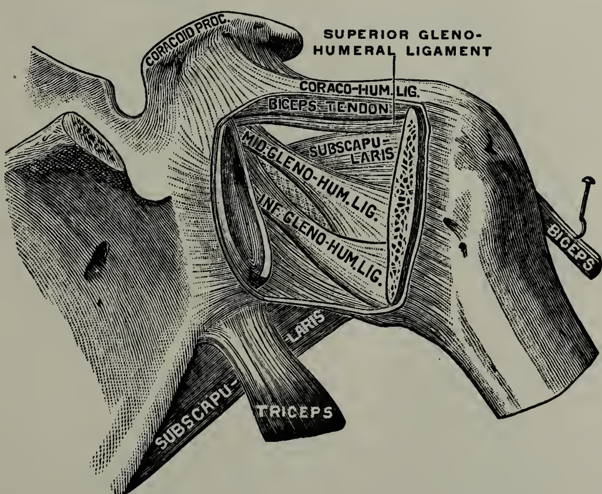


FIG. 108.—Shoulder-joint, rear view. The hind part of the capsular ligament and most of the head of the humerus have been removed. (Testut.)

The Shoulder-joint.—The parts concerned are the rounded head of the humerus and the glenoid fossa of the scapula. Both surfaces are covered with cartilage, and around the edge of the fossa to deepen it is a rim of fibrocartilage, the *glenoid ligament,* which is triangular on cross-section. From the circumference of the fossa the capsular ligament extends to the anatomical neck of the humerus. This capsule is longer than the actual distance requires, but allows

great mobility in the joint. The synovial membrane lines the capsule extending down into the bicipital canal. The capsular ligament does not hold the bones together, but as a vacuum exists within the capsule, atmospheric pressure does. Various tendons serve to help prevent dislocation. That of the biceps muscle goes within the capsule, and to the upper border of the fossa, guarding the joint above. This is noticeable when the arm is in abduction, and the latissimus dorsi and pectoralis major muscles are pulling it downward, as in hanging by the hands. Tendons of supraspinatus, infraspinatus and teres minor muscles are above and posterior; that of the triceps muscle below, the subscapularis muscle in front. Between these two latter is an unprotected space, through which, under violent strain, the head of the humerus may be dislocated, instead of having a worse injury to the joint structures.

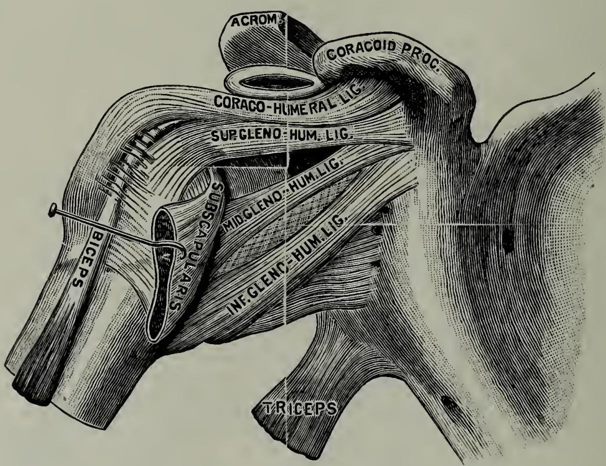


Fig. 109.—Shoulder-joint, front view. (Testut.)

The inner surface of the front of the capsule is further strengthened by three bands, *gleno-humeral,* passing from the edge of the fossa to the greater tuberosity of the humerus. Strong bands pass from the coracoid process of the scapula to the anatomical neck of the humerus, in close association with the capsule.

The shoulder-joint is a ball-and-socket joint, allowing movement in all directions, flexion, extension, rotation, abduction, adduction and circumduction. Flexion and extension, abduction and adduction are possible through 90 degrees. In abduction, the head of the humerus is prevented from going further by the greater tuberosity striking against the acromion process and by the coraco-acromial ligament.

Before the arm has gone far in these movements, the glenoid fossa begins to turn, so complete extension or abduction takes place by the combination of rotation of the scapula, and the movement at the shoulder-joint.

Inward and outward rotation· occurs around an axis from the center of the head to the inner condyle of the humerus, with a range of about 90 degrees.

The subacromial bursa between the capsule and the deltoid muscle is important to remember. This bursa is continued under the acromion, between it and the capsule. It facilitates abduction of the arm. Seven other bursæ are in relation with the shoulder-joint.

This joint is remarkable for several features: the large size of the head to be received in a small socket, which, with the looseness of the capsule, provides for a wide range of motion; the movements at the sterno-clavicular and acromio-clavicular joints, by which the rotation of the scapula supplements the movement in the shoulder-joint; the capsule does not regulate the movements of the joints, but this is done by the surrounding muscles; and the relation of the tendon of the long head of the biceps, which is inside the capsule. By this device, the head of the humerus is prevented from being pressed against the acromion, during the abduction of the arm. The head of the bone is made more steady in its socket, as well as being kept in contact with it, preventing its slipping over the lower edge, in such movements as hanging by the arm.

FIG. 110.—Elbow-joint, mesial view. (Poirier.)

The Elbow-joint.—This is formed by the trochlear surface of the humerus and the greater sigmoid cavity of the ulna. Both surfaces

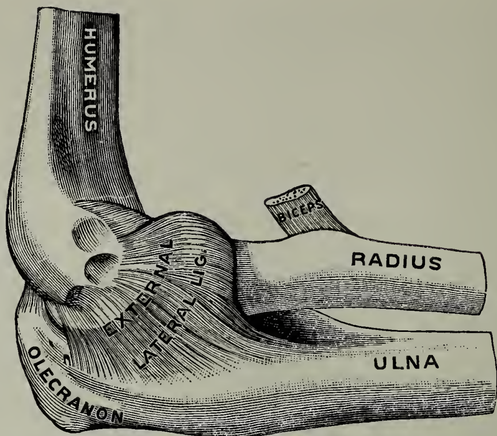


Fig. 111.—Elbow-joint, outer side. (Testut.)

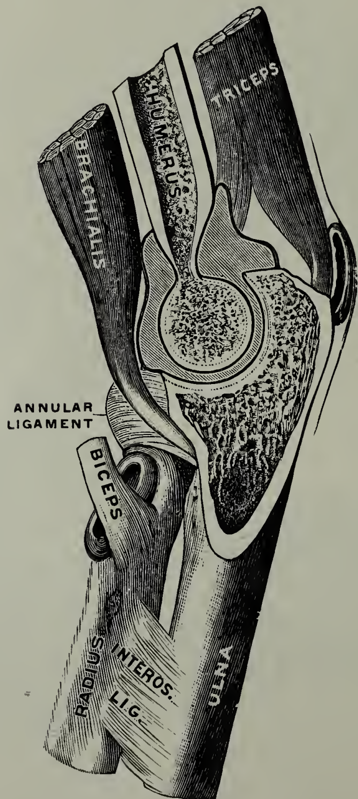


Fig. 112.—Elbow-joint in sagittal section, showing the articular synovial sac and the bursæ of the olecranon and the biceps. (Testut.)

are covered with cartilage, with a capsule surrounding the joint and bands of fibers accentuating the internal, external, anterior, and posterior aspects. Of these, the internal lateral bands are the strongest. The anterior fibers are attached to the brachialis muscle, which contracts in flexion of the elbow, and draws the capsule out of the way of being pinched by the bony margins. The triceps muscle acts similarly for the posterior fibers. The capsule is lined by synovial membrane which is continued into the fossæ about the joint.

This is a hinge joint, allowing flexion and extension around an oblique axis inclined at an angle of 84 degrees with the shaft of the humerus. In flexion of the forearm, the hand moves toward the middle line of the body, and *vice versa* in extension. The head of the radius moves on the capitellum and aids in preventing side displacement of the bones. In the semi-flexed position of the elbow movement of the radial head in pronation and supination is most free.

The tendons of the biceps, brachialis and triceps muscles do much to strengthen this joint (Fig. 112).

The Radio-ulnar Articulations.—The radio-ulnar articulations consist of two joints and a fibrous union. The *superior*, formed by the head of the radius pivoting in the lesser sigmoid cavity of the ulna, has the orbicular ligament surrounding, and holding it as in a sling. Its movements in connection with the inferior radio-ulnar articulation are pronation (turning the palm downward), and supination (turning the palm upward). The fibrous union between the two bones of the forearm consists of an oblique band above and the interosseous ligament below, extending to the lower articulation. As these fibers are obliquely placed the space between the bones is greater during supination. The *inferior* radio-ulnar joint is formed by the head of the ulna in the sigmoid cavity of the radius. It is closely associated with the wrist-joint by the triangular fibrocartilage which connects the radius and ulna, and separates the ulna from the wrist-joint. It is enclosed by a capsular ligament. The lower end of the radius moves about the ulna in rotation, carrying the hand with it.

The Wrist-joint.—The wrist is a condyloid joint, formed by the lower end of the radius and carpal bones, *scaphoid* and *semilunar*. The lower end of the ulna is separated from the joint by the triangular fibrocartilage, the lower surface of which articulates with the upper surface of the *cuneiform*.

Bands of fibers, anterior, posterior, internal, and external lateral form a capsule which is lined by synovial membrane. The posterior aspect of the joint is strengthened by the tendons of the extensor muscles of the hand and fingers.

The Carpal Articulations.—The carpal articulations consist of bands of fibrous tissue connecting the various carpal bones to each other, front, back, and in between. Fibers between the carpal and metacarpal, the metacarpal and phalanges, are on all sides.

The phalanges are united with each other by capsular ligaments.

The Movements of the Wrist and Hand.—Movements of the wrist-joint are flexion, extension, abduction, adduction, and circumduction, but not rotation.

The carpal bones form gliding joints with each other, and provide considerable elasticity, which lessens shock. Exclusive of the first and fifth, the carpo-metacarpo joints allow flexion and extension. The fifth provides for a greater amount of these movements, and the direction of the flexion is outward, so cupping the hand and causing opposition of the little finger. The joint of the metacarpal of the thumb and corresponding carpal bone is of reciprocal reception, with flexion, extension, abduction, adduction and circumduction. Flexion is obliquely forward and inward allowing the opposition of the thumb to any and all of the fingers.

The metacarpo-phalangeal joints are condyloid, with the usual movements, excepting that the first allows only flexion and extension.

The various joints of the hand combine to allow prehension and a variety of movements characteristic of man.

THE PELVIC ARTICULATIONS.

The fifth lumbar vertebra articulates with the upper surface of the sacrum, and very strong ligaments hold them together. The fibrocartilaginous disk between them is especially thick, so allowing free flexion and extension, as in sitting, or in rising from the sitting position. The inclination of the pelvis depends partly upon the relative position of these bones, and upon the relation between the sacrum and ilium at the sacro-iliac synchondrosis. The articulations between the sacrum and coccyx, and between the segments of the coccyx, allows a small amount of motion.

The Sacro-iliac Synchondrosis.—The sacro-iliac synchondrosis is formed by the union of their two auricular surfaces, connected by very strong ligaments, especially those posterior. Cartilage covers the joint surfaces. This is called an amphiarthrodial joint, as a slight gliding of the joint surface is possible. Normally, no motion occurs.

The Symphysis Pubis.—The symphysis pubis, or joint between the two pubic bones, has a disk of fibrocartilage between, with ligaments above, below, front, and back. As with the preceding joint, the structure is amphiarthrodial, with the possibility of

gliding movement. During pregnancy, these joints may become more or less relaxed.

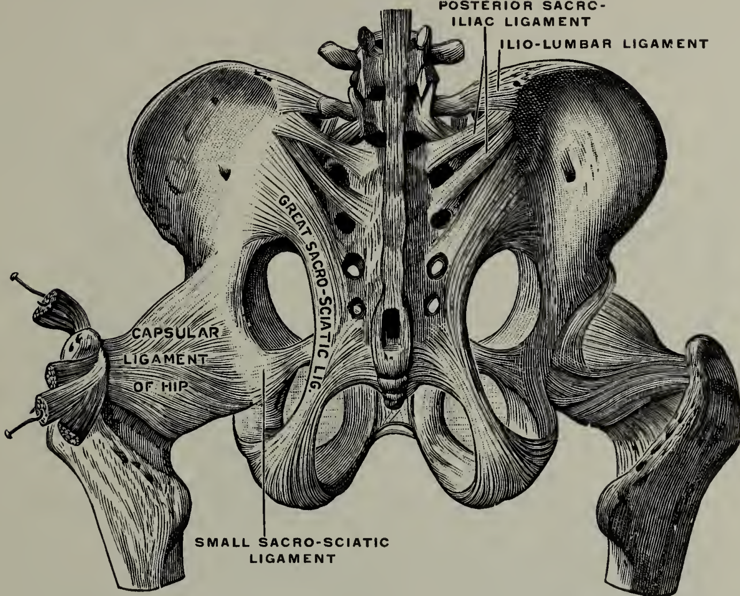


FIG. 113.—Articulations of the pelvis, rear view. (Testut.)

THE ARTICULATIONS OF THE LOWER EXTREMITY.

The Hip-joint.—The hip-joint is analogous to the shoulder-joint in the upper extremity. It is formed by the rounded head of the femur, and the acetabulum. The surfaces are prepared by the covering of cartilage. Around the edge of the acetabulum is a rim of fibrocartilage, the *cotyloid* ligament, which deepens the cavity to better fit the head of the femur, and constricts the circumference to lessen the possibility of the head leaving the socket. The notch at the lower border is bridged by the transverse ligament, forming a foramen through which passes nerves and bloodvessels. Attached to the head of the femur, and going to the bottom of the cavity, is a band, the *ligamentum teres,* which holds the femur in the socket, even after the capsular ligament is removed. Coming from the rim of the acetabulum, beyond the cotyloid ligament is a sheath of fibrous tissue, the *capsular* ligament. This extends to the anterior intertrochanteric line in front, and ½ inch internal to the posterior intertrochanteric line behind.

On the outside of the capsule are three accessory bands, of which the first is most important. The *ilio-femoral* band, or "Y" ligament of Bigelow, is shaped like an inverted "Y" with the stem

attached to the anterior-inferior iliac spine, and the wide lower end to the anterior intertrochanteric line. This is the strongest ligament in the body. The *pubo-femoral* band passes from the pubic bone to the femur. Between this and the ilio-femoral band, the capsule is thinner and weaker, allowing dislocation This provision may prevent greater injury from external violence to the joint. The third accessory band, the *ischio-femoral,* passes from the ischium just below the acetabulum to the base of the great trochanter.

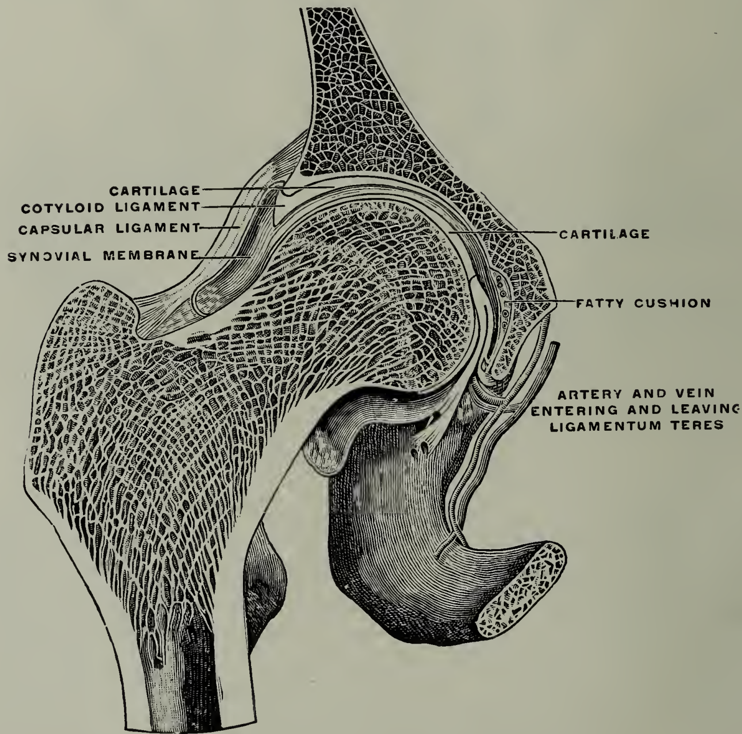


Fig. 114.—Hip-joint in coronal section. (Testut.)

The capsule is further strengthened by fibers from the tendinous sheath of various muscles. The ilio-psoas in front; the pectineus on the inner side; obturator externus behind and below; obturator internus, two gemelli, and pyriformis behind, and the rectus femoris and gluteus minimus externally. The capsule is lined by a synovial membrane, which is reflected on to the neck of the femur, and surrounds the *ligamentum teres.*

This ball-and-socket joint allows movements in all directions, though their extent is less than those of the shoulder-joint. Flexion and extension occur without the head of the femur leaving the

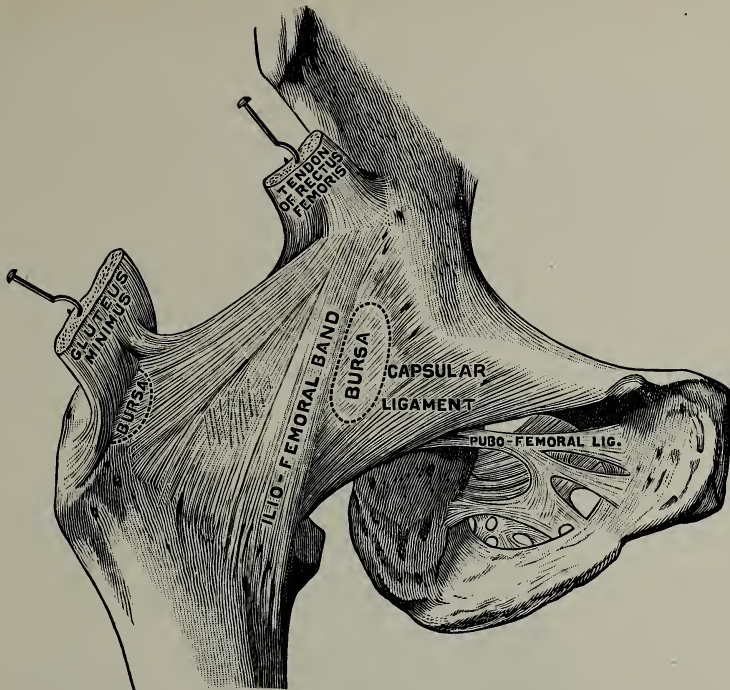


FIG. 115.—Hip-joint, front view. The cavity is distended artificially. (Testut.)

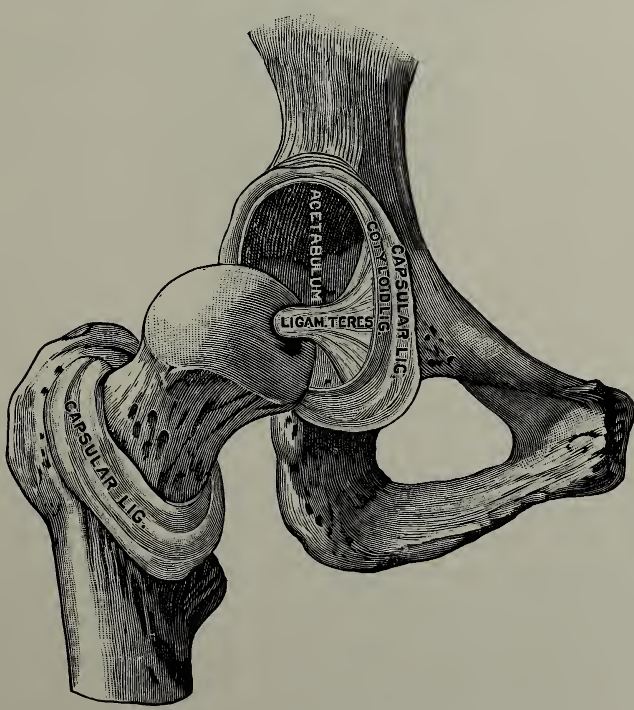


FIG. 116.—Hip-joint, front view. The capsular ligament has been largely removed, (Testut.)

socket. This is true for none of the other movements. Extension is limited by the "Y" ligament, which also helps to prevent the trunk falling backward. It allows the erect position to be maintained without muscular fatigue. If, at the same time, the knee flexes, flexion takes place to 140 degrees, until limited by the contact of the thigh with the abdominal wall. If the knee is extended, the resistance of the hamstrings stops the movement at 90 degrees. The movement of adduction is checked by the contact of the thighs. Abduction is checked by the middle part of the "Y" ligament. Outward rotation is limited by the lateral portion of the same ligament, with inward rotation checked by the ischio-femoral band and the capsule.

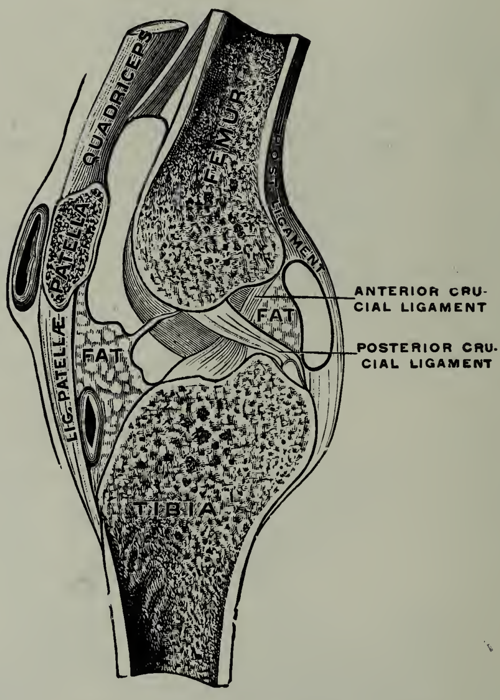


FIG. 117.—Knee-joint in sagittal section. (Testut.)

The Knee-joint.—The knee-joint is formed by the condyles of the femur, the upper surface of the tibia, and the patella.

To the cartilage-covered surface of the tibia are applied two disks of fibrocartilage, somewhat horse-shoe shaped, and called *semilunar* cartilages. These are to deepen the cavity. The disks are thicker on the outer edges, at which they are loosely attached to the bone by the *coronary* ligaments, with the *transverse* ligament going from one to the other in front.

The bones are held together by two *crucial* ligaments, anterior and posterior, which arise from in front of and behind the spine of the tibia, and are inserted into the contiguous surfaces of the two condyles. The *patella*, a sesamoid bone in the tendon of the quadriceps extensor cruris muscle, forms the front part of the joint, moving up and down over the trochlear surface of the femur, in extension and flexion of the joint.

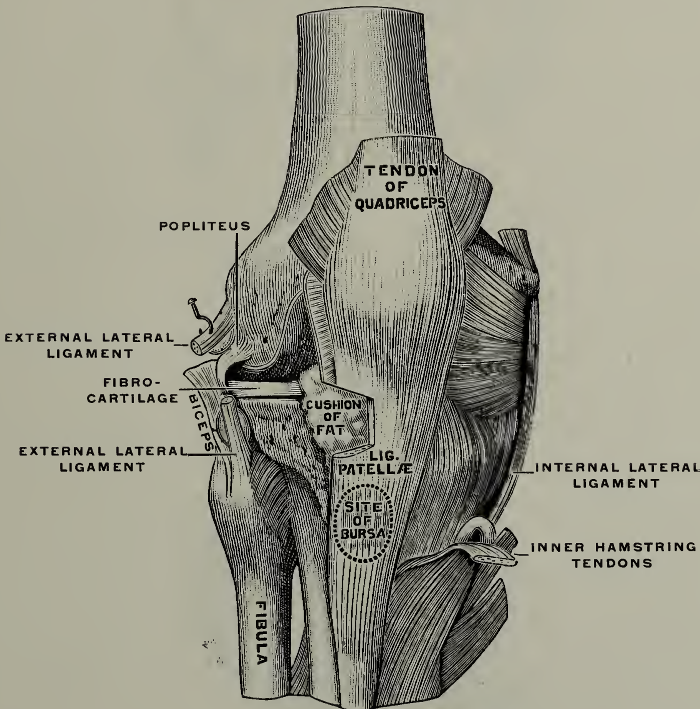


FIG. 118.—Knee-joint, front view. Part of the ligaments have been removed on the right side. (Testut.)

Surrounding the joint on all sides are bands, which are connected by additional fibers to form a complete capsule. The tendon of the quadriceps muscle, inserted into the tubercle of the *tibia* and sometimes called the *ligamentum patellæ*, forms the front part of the capsule. Posteriorly, oblique fibers, the *ligamentum Winslowii;* laterally, one internal, two external ligaments, complete the covering of a joint that is said to be made up of three joints fused together. There is good authority for considering the knee-joint as comprising a joint between the outer condyle of the femur and the external semilunar cartilage; the inner condyle and the internal semilunar

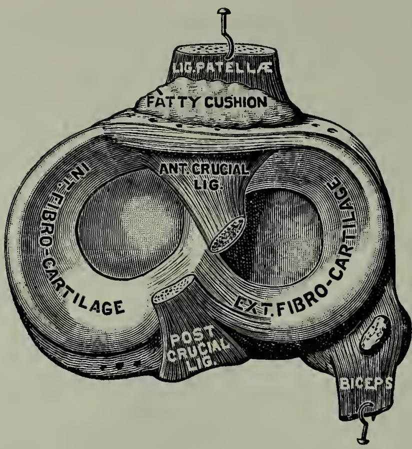


FIG. 119.—The semilunar cartilages of the right knee-joint. (Testut.)

FIG. 120.—Knee-joint, outer side. The synovial sacs are artificially distended. (Poirier.)

cartilage, with the third joint between the patella and the trochlear surface of the femur.

A most extensive synovial membrane lines the capsule, covers the semilunar cartilages and crucial ligaments. It communicates with numerous bursæ around the joint, and forms a crescentic fold within the joint called the *ligamentum mucosa.* This projects from the front of the capsule backward and upward to the front of the intercondyloid notch. The ends of the fold form the *alar ligaments.* Small masses of fat help to fill the spaces between the bones and to form cushions.

The knee-joint has many bursæ, some of which communicate with the main synovial cavity. Some of the most constant and important ones are those between the bones and the tendons passing on each side of the popliteal space; above and beneath the *ligamentum patellæ;* over the patella; between the inner hamstring and the head of the tibia, and over the tubercle of the tibia.

The knee is a modified hinge-joint with flexion and extension around an axis that shifts forward *during extension* and backward *during flexion.* On account of the shallowness of the cavities on the upper surface of the tibia, and the curves of the condyles, the surfaces cannot remain in constant close contact. The crucial ligaments hold the bones together and prevent the tibia being carried too far backward or forward. At the end of the movement of extension, there is a slight outward rotation of the leg, shown by the outward pointing of the foot. This is reversed at the beginning of flexion. The hinge movement takes place between the condyles of the femur and the semilunar cartilages. The rotation occurs between the cartilages and the head of the tibia. In descending a slope, the foot naturally turns out, and *vice versa.* The tendons of the quadriceps, the hamstrings, inner and outer, the gastrocnemius and the popliteus muscles serve as supplementary ligaments to protect this joint. They are so adjusted that overextension of the joint is resisted by them, enabling the body to maintain the erect position with little muscular effort.

The Articulations of the Tibia and Fibula.—The articulations of the tibia and fibula are in three parts, upper, lower and middle. Bands of fibers passing from bone to bone join the head of the fibula to the facet on the outer tuberosity of the tibia. An interosseous membrane connects them throughout their length. The oblique direction of these fibers allows a slight gliding of the bones on each other, so that during flexion of the ankle there is a widening of the mortise part of the mortise and tenon of the ankle. The lower articulation is between the internal malleolus of the femur and the astragalus. As this forms a part of the ankle-joint, the description is included with that of the latter.

Ankle-joint.—This is formed by the *internal* and *external malleoli* and the *astragalus.* The lower ends of the tibia and fibula form a mortise into which the astragalus fits as a tenon, giving a very strong structure to prevent lateral displacement, and to resist the tremendous leverage exerted by the height and weight of the body.

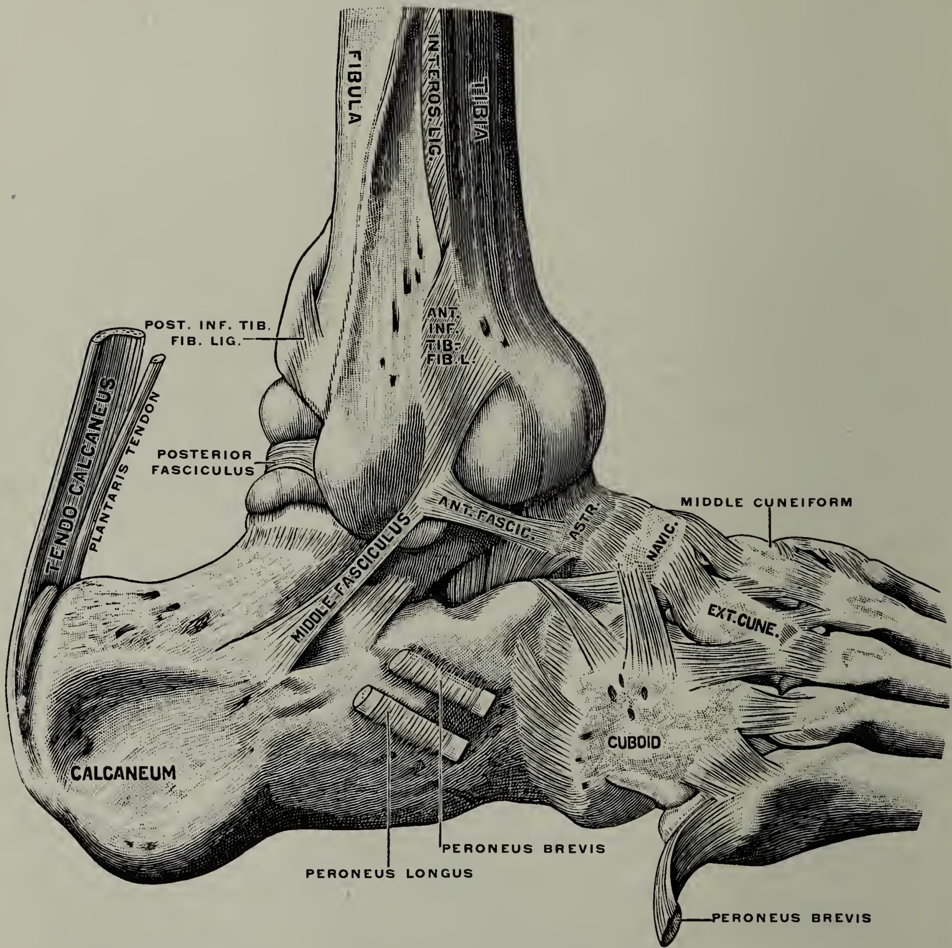


Fig. 121.—Tibio-tarsal articulation, outer side. The cavity is artificially distended (Testut.)

The joint is closed in by a capsule, with ligaments on all four aspects, especially lateral.

The anterior fibers pass from the front of the tibia to the upper part of the astragalus; the posterior fibers from the back in the same way. The external lateral is divided into three fasciculi, anterior,

middle and posterior. The anterior bundle passes from the front of the external malleolus to the front of the astragalus; the middle bundle from the tip of the external malleolus to the os calcis; the posterior from the back of the malleolus to the outer surface of the astragalus. The internal lateral or deltoid ligament, triangular in shape, is attached by its apex to the tip of the internal malleolus, with its base inserted on the inner surface of the astragalus, the sustentaculum tali of the calcaneum, the scaphoid, and to the inferior calcaneo-navicular ligament.

The tendons of the muscles that move the ankle-joint, the tarsal joints, and the toes are in close relation to this joint, and act as supplementary ligaments. Bursæ lie between the skin and the two malleoli.

A hinge movement is permitted in the ankle-joint, to less than 90 degrees. The axis of this movement is slightly oblique, and so helps to secure a stable equilibrium in standing. The movements of the ankle-joint are closely associated with those of the medio-tarsal articulation. The combined action of the muscles acting on both has much to do with maintaining the balance in both standing and walking.

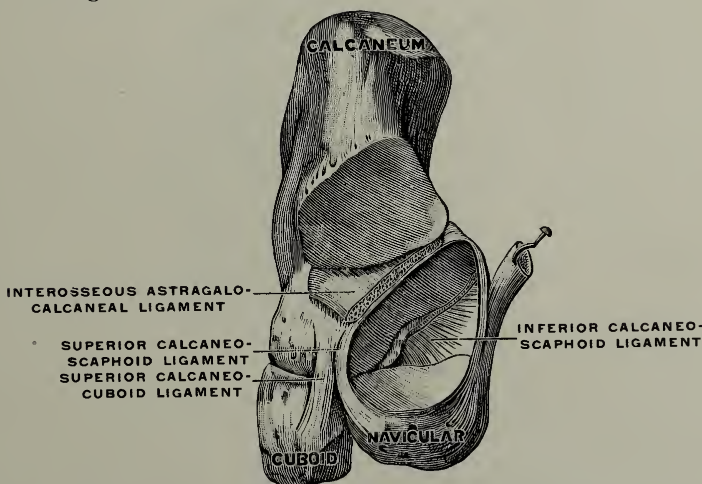


Fig. 122.—Medio-tarsal joint, viewed from above, the astragalus having been removed. (Testut.)

The Tarsal Articulations.—As in the carpal joints, the various bones of the foot are held together to form gliding joints which allow a small amount of motion, and provide for elasticity and shock absorption.

The calcaneum and the astragalus have two articulations, anterior and posterior. The latter forms a gliding joint. The anterior

articulation makes a connection with the scaphoid or navicular by means of the inferior and superior calcaneo-scaphoid ligaments, forming the astragalo-calcaneo-scaphoid articulation, an arthrodial joint allowing quite free gliding and rotation.

The calcaneo-scaphoid ligaments, called the "spring ligaments," are partly cartilaginous (hence elastic), and give support to the head of the astragalus or talus. Because of this supporting function, the ligament is intimately associated with maintaining the arch of the foot. If it gives way, by reason of weakness of the

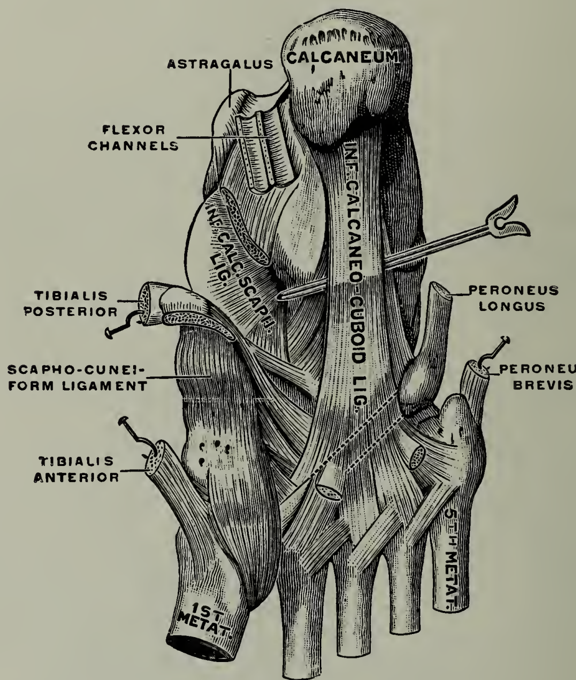


FIG. 123.—The plantar ligaments. (Testut.)

associated muscles, the weight of the body transmitted through the ankle-joint to the astragalus causes this bone to come downward, inward, and forward. The arch is flattened, the inner border lowered, the front of the foot turned outward, in the typical "flat-foot." The integrity of the ligament is largely dependent upon the tonicity of the tibialis posticus muscle, whose tendon spreads out under the head of the talus.

On the outer side of the foot, the cuboid and calcaneum articulate. Connecting them are the strong fibers of the short plantar ligament nearer the bones. Superficial is the long plantar ligaments, whose

fibers pass forward to the bases of the second, third, and fourth metatarsals.

The groove on the under surface of the cuboid is covered by this long ligament, converting it into a canal for the tendon of the peroneus longus.

In general, it may be said that the bones as a whole are enveloped in fibrous ligaments which cover the dorsum and sole of the foot, with ligaments between the bones. The heads of the metatarsals are connected by the *transverse metatarsal* ligament. The flexor tendons run beneath it, giving it support.

The calcaneo-cuboid articulation on the outer side of the foot, with the astragalo-scaphoid union, forms a joint right across the foot, separating the front from the hind part which is called the medio-tarsal articulation.

The movements at the calcaneo-astragaloid joint are inversion, eversion, adduction, and abduction. These, as well as flexion and extension, also occur in the medio-tarsal joint.

Flexion at the medio-tarsal is associated with extension at the ankle, and the reverse. The joint between the astragalus and scaphoid is a ball-and-socket, but its motion is limited by its association with the condyloid joint between the calcaneum and cuboid.

In the medio-tarsal joint, flexion of the foot is combined with inversion of the sole and adduction of the front of the foot. If this position is exaggerated and permanent, the condition of "club foot" results. If the reverse obtains, or extension with eversion of the sole and abduction of the front, the "flat foot" or "pronated foot" is produced.

Note.—Some prefer to speak of the movement of flexion at the ankle, as dorsi-flexion. It should be remembered that the muscles that flex the toes extend the ankle, and *vice versa*.

The three cuneiform bones are united to all the bones in contact with them, and form gliding joints, as is the case in the tarso-metatarsal joints. In the metatarso-phalangeal articulations, which are condyloid, abduction and adduction take place from and toward a line passing through the second toe. Flexion and extension in these, and in the phalangeal joints, are also permitted. Abduction and adduction take place from, and toward, the middle of the second toe. The interphalangeal joints allow flexion and extension, only.

The mechanism of the foot is designed for standing and locomotion. The balanced action of the various muscles acting upon the ankle and bones of the foot should hold it in a position in which the ligaments are not strained, but in which the long and transverse arches operate to insure elasticity and strength.

The Arches of the Foot.—The bones of the foot are arranged to form arches, connected by ligaments, and strengthened by the

tendons of muscles passing over them. The principal arches are two longitudinal, and several that are transverse, including one that is called the anterior transverse arch (Figs. 101 and 102).

The *medial longitudinal arch* is formed by the astragalus (or talus), the calcaneum, the scaphoid, the three cuneiforms, and the first, second, and third metatarsals. Of these the astragalus is the keystone, with the calcaneum forming the posterior extremity, and the heads of the three metatarsals the anterior extremity of the arch. This is the highest arch of the foot. On account of this feature, and the fact that the articulations between the various bones allow gliding movements, considerable elasticity is attained. The weight of the body presses it down, but when the weight is removed the arch returns to its former height. A special feature that adds to this elasticity is the calcaneo-scaphoid ligament, partly cartilaginous, on which the head of the astragalus rests. Its strength is increased by the association of the deltoid ligament of the ankle-joint, the aponeurosis in the sole of the foot, the small muscles in this locality, the tendons of the tibialis anterior and posterior, and that of the peroneus longus.

The *lateral longitudinal arch* is formed by the calcaneum, the cuboid, with the two outer metatarsals. The highest point is at the juncture of the astragalus and calcaneum. This arch is quite firm, as there is but little movement allowed at the calcaneo-cuboid, its principal articulation. It is strengthened by the plantar ligaments, the extensor tendons, and the small muscles of the little toe.

"While these medial and lateral arches may be readily demonstrated as the component antero-posterior arches of the foot, yet the *fundamental longitudinal arch* is contributed to by both, and consists of the calcaneum, cuboid, third cuneiform, and third metatarsal; all the other bones of the foot may be removed without destroying this arch." (Gray.)

The *anterior transverse arch* has its inner pier at the internal cuneiform and the first metatarsal; the outer pier is at the cuboid and the fifth metatarsal. This forms a complete arch, under which pass nerves and bloodvessels. It is strengthened by ligaments on the sole and dorsum of the foot, the small muscles of the great and little toes, and especially by the fibers of the adductor hallucis transversus, and the tendon of the peroneus longus.

Several partial arches cross the foot, forming half domes. If the two feet are placed side by side, domes are formed by these partial arches. Architecturally, the dome is the strongest form of support for weight.

These various arches provide spring in walking or in jumping. They add much to the beauty of the feet.

THE RELATION OF MUSCLES AND TENDONS TO JOINTS.

Under ordinary conditions the ligaments are sufficient to hold together the bones which form a joint. They do not prevent displacement or dislocation under sudden, severe strain, or from long-continued moderate strain. The provision for further protection is found in the muscles and tendons which pass over the joint. These are held in close contact with the joint by the deep fascia which is continuous with the fibrous tissue of which the ligaments are composed.

Notice where the tendon of insertion of the biceps humeris comes, in relation to the elbow-joint, as well as the location of the two points of origin at the shoulder-joint. When the biceps contracts it prevents the head of the humerus from slipping forward out of the glenoid fossa. It also helps to keep the radius from slipping off the capitellum.

The more motion the joint is allowed by its structure, the more completely it is guarded by muscles. Suddenly applied external force, acting on a joint when the muscles are "off guard" is likely to produce dislocation.

A demonstration of this may be made by grasping an overhead bar, and letting the weight hang loosely. Care must be taken to keep the feet on the floor, so that too much of the weight is not so suspended.

In "faulty standing" the weight depends upon "ligamentous support, instead of upon tonic muscles. This may result in more or less bony displacement, as "sprung knees."

QUESTIONS.

Describe a typical *joint.*

What *movements* are possible in joints?

How much movement is possible in the *spinal column*, and in what direction?

What *articulations* provide for the movements of the head?

Describe the shoulder-joint.

What joints provide for pronation and supination of the hand?

What relation has the strength of the ligaments of the sacro-iliac synchondrosis to the maintenance of the erect position?

Compare the structure and movements of the hip- and shoulder-joints.

What are the "semilunar cartilages?"

What are the "crucial" ligaments?

How many joints are combined in the knee-joint?

Describe the ankle-joint.

What movements of the foot take place at the tarsal and medio-tarsal joints?

What are the articulations of the thorax, and how are the movements related to respiration?

How does Nature provide for the dislocation of a joint to save greater injury?

CHAPTER V.

THE MUSCULAR SYSTEM.

Note.—Before beginning the study of this chapter, the account of the histology of muscle tissue, beginning on page 50, should be reviewed.

The Skeletal Muscles.—Two-fifths of the weight of the body is composed of the skeletal muscles. Through the motor nerves, they are under the control of the will, providing for prehension, locomotion, and a multitude of determined, coördinated movements.

The skeletal muscles almost completely envelop the bony framework of the body, cover in the abdomen, and separate the thoracic from the abdominal cavity. They are found in connection with the eye, ear, nose, mouth, and throat.

The Form of Muscles.—According to their work, the size and shape of muscles vary, from the broad, thin sheets that cover cavities, to the longer, narrower, spindle-shaped ones that move such parts as the extremities. The arrangement of the fibers vary according to their relation to the tendon. When the attachments on two bones are of the same length, the fibers are placed side by side, forming a quadrangle, as the pronator quadratus. If the fibers are side by side, with the areas of attachment small, the muscle becomes fusiform or spindle-shaped, as the biceps. From an extensive attachment the fibers may slope toward a tendon placed on one side—the "pennate" form. Or, the fibers may slope toward a central tendon, the "bipennate" form, as in the central portion of the deltoideus. In proportion to size or bulk, this arrangement gives the most strength.

The fleshy, elastic part of a muscle is called the "belly." It is the active portion, shortening in contraction. The inactive portion is the tendon, transmitting the pull of the contracting part.

Composition of Muscles.—Viewed by the naked eye, muscles show an arrangement of bundles of pink or red color. These bundles consist of bundles of bundles, until in the microscopic examination of the tissue we find the ultimate unit to be a single fiber, which has incorporated within it a motor nerve. Each ultimate fiber has a sheath of fibrous tissue. As the fibers form a bundle, the extension of the sheath forms a cord-like process which helps to form the tendon of the muscle. Successive bundles are formed, with the sheaths becoming heavier as they cover larger bundles. These sheaths are called "fasciæ."

Fasciæ.—The fascia that covers a muscle helps join one to another, as well as to separate them. These layers of fibrous tissue between the muscles are called the *deep fascia,* or *intermuscular septa.* They also provide areas of attachment for other muscles. Covering in the musculature of a limb, or other part, the fibrous investment is called the *superficial fascia,* being directly under the skin. In Chapter IX the relation of the fascia to the veins that drain the extremities will be considered. Fascia is considered in detail in Chapter VI.

Tendons.—The tendons attach the muscles to bones, occasionally to other muscles. The shape of the muscle and the areas of attachment determine the conformation of tendons. A long, narrow muscle inserted on a small elevation of bone has a cord-like tendon. Such can be felt on the dorsum of the hand. On the back of the forearm, for the greater part of its length, the ulna can be felt. This surface is covered with the spread-out tendon (aponeurosis) of three muscles. (Fig. 135.)

Tendinous Inscriptions.—In a few muscles, such as the rectus abdominis, the muscle is relatively long, extending from the lower ribs to the pelvis. A part of the work of this muscle is to compress the abdominal viscera. For this reason, there are four sets of short fibers separated by three crosswise tendinous inscriptions (page 210). The more powerfully such muscles are developed, the more marked are the inscriptions.

The Action of Muscles.—Muscles never work singly, but always in groups. It is not possible to contract one muscle in a group. The nerve supply seems to be localized in the brain to cause coördinated contractions that accomplish some definite action. Each muscle fiber has its own motor nerve, the aggregation of fibers producing a nerve cord which runs between the muscles. This is in company with the artery supplying the part, and the vein that drains it. When the impulse from the brain, through the motor nerve, reaches the muscle, it contracts, making the belly shorter and wider. The tendon, made of inextensible material, transmits the pull to the movable bone, without changing its own length. To have one attachment of a muscle steady, while the other end moves, it is necessary for a group of muscles, called "fixator" muscles, to hold one end fixed. For instance, if the biceps contracts, to flex the elbow, its origin on the scapula is held practically immovable by the muscles attached to the upper part of the humerus. Usually the extensors of a part is on one side of an extremity, while the flexors are on the other side. If they both contract with equal force, the bone does not move, but is held firm.

The usual action of a muscle from a fixed origin to a movable insertion is called its *direct* action. When a fixed insertion acts upon a movable origin, the action is called its *reversed* action.

Muscles passing over more than one joint are said to have a

primary action on the first joint, a secondary action on the next, and a tertiary action on the third if the contraction continues. These terms apply to muscles that act upon two or more joints as either flexors or extensors. For instance, the flexor of the fingers that is inserted in the base of the last phalanx of the finger has a primary action on the joint next above; a secondary action on the next to that, and a tertiary action on the metacarpo-phalangeal joint.

Ligamentous Action of Muscles.—In the lower extremity certain muscles which pass over two joints, by the so-called "ligamentous action," serve as extensors of one and flexors of the other. Such muscles are known as "two-joint muscles." (See notes on page 190 in reference to the flexors of the leg.)

"The movements of the different joints of a limb are combined by means of the long muscles passing over more than one joint. These, when relaxed and stretched to their greatest extent, act as elastic ligaments in restraining certain movements of one joint, except when combined with corresponding movements of the other, the latter movements being usually in the opposite direction. Thus the shortness of the hamstring muscles prevents complete flexion of the hip, unless the knee-joint is also flexed, so as to bring their attachments nearer together. The uses of this arrangement are threefold: (1) It coördinates the kinds of movements which are the most habitual and necessary, and enables them to be performed with the least expenditure of power. (2) It enables the short muscles which pass over only one joint to act upon more than one. (3) It provides the joints with ligaments which, while they are of very great power in resisting movements to an extent incompatible with the mechanism of the joint, at the same time spontaneously yield when necessary." (Gray.)

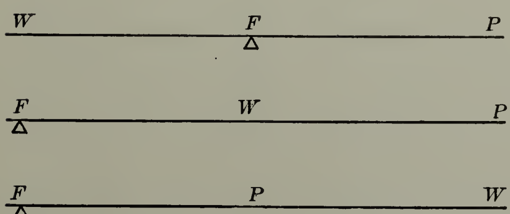
The Strength of Muscles.—The strength of muscles depends upon the number of fibers in the physiological cross-section. The fibers are not all of the same length, varying from 9 to 30 mm. A cross-section through practically all the fibers of a muscle is called a "physiological cross-section." It is the basis on which the power of a muscle may be estimated. The average strength has been figured as about 10 kg. to the square centimeter of physiological cross-section. A muscle made up of many short fibers is stronger than one of fewer fibers of greater length.

Origins and Insertions of Muscles.—It is customary to speak of the fixed end as the origin and of the moving end as the insertion of muscle. While this is convenient, it is not always true to fact, as the conditions are frequently reversed. These terms are also used to indicate the proximal and distal ends of the muscle, the origin being that attachment nearest the center of the body or nearest the head, and the insertion that more distant. The point where the power is applied is also called the insertion. If we define

the *origin* as the fixed point, we can cite the biceps as showing the term may be inaccurate. The two scapular attachments of the biceps, in the anatomical position of the body, *i. e.*, the standing position, with arms hanging, and the hands facing forward, could be called origins. When hanging by the hands and drawing the body upward, the radial attachment is the fixed point and may be called the origin. It is evident that the terms do not always express the arbitrary meaning. In describing the muscles it is preferable to speak of their attachments, rather than of origin and insertion. However, for convenience, in the tabulated account of the muscles, the terms origin and insertion are used as the body is supposed to be in the "anatomical position." (Figs. 2 and 3.)

Muscles as Levers.—The application of the power of muscles should be considered from the standpoint of mechanics. The bones and muscles constitute a series of levers. Briefly a lever is a means to obtain movement more or less economically by applying power. If one wants to move a stone which is too heavy to lift by the arms, the lever makes the thing possible. By inserting the end of a bar under the edge of the stone, then pressing down upon the farther end of the bar, the stone is easily moved. The leverage of the bar increases many fold the power of the individual. The saying of Archimedes becomes comprehensible, *i. e.*, "Give me a place upon which to stand and a long enough lever, and I will move the earth."

Levers are divided into three classes, according to the relative positions of the weight to be moved: the point of applying power and the fulcrum around which the weight moves. Let F represent the fulcrum; W the weight and P the power. The lever in which F is in the middle is of the first class. That in which the weight is in the middle is of the second class, and that in which the power is in the middle is of the third class. The following diagram will make this clear.



LEVER OF THE FIRST CLASS

LEVER OF THE SECOND CLASS

LEVER OF THE THIRD CLASS

The majority of the muscles of the body belong to the third class of levers. While these are rather wasteful of power, there are compensating advantages, such as increased speed of movement, more beauty of form, greater convenience in use, as well as additional

security of joints. It will be observed that usually the point of application of the power is quite near the fulcrum. This arrangement is also wasteful of power, but it prevents awkwardness of form. In the biceps, the power for flexing the forearm is applied just below the elbow (which is the fulcrum), instead of in the more economical way, at the wrist. This obviates the need for a long, clumsy appearing muscle, extending from shoulder to wrist. The elbow-joint is strengthened by the bicipital tendon lying close.

Tonicity of Muscles.—If a muscle is cut, in a living animal, the two ends separate. This indicates a condition of slight contraction, which, to a greater or less degree, is constant. It is *muscle tonus*, or tonicity, and is manifest as more or less firmness or hardness of consistency. Thereby the muscle is enabled to promptly respond to stimulation. Vigorously used muscles are more "tonic" than those that have little exercise. The opposite condition is *flaccidity*, which occurs when motor impulses are cut off from the muscle, as in "infantile paralysis." Flaccidity is characterized by a marked softness of consistency.

Apparently the normal tonus is a reflex, depending upon slight afferent impulses from the periphery reaching cells in the spinal cord, initiating slight motor impulses which go thence to the muscles.

THE PHYSIOLOGY OF MUSCLES.

Nervous Stimuli.—The normal stimulus through which muscles contract is that from the motor nerves.

A single stimulus is followed by a single contraction with subsequent relaxation. The stronger the stimulus, the greater the contraction. With stimuli of the same intensity, repeated several times, the contraction increases. This is supposed to be due to the stimulating effects of the waste products developed in the muscle fiber.

Many experiments have been made with what is known as a "muscle-nerve" preparation. This consists of the excised gastrocnemius muscle, with the sciatic nerve of a frog. It is connected with a recording apparatus in which the changes in length of the muscle is recorded by a needle moving on a revolving, smoked-paper-covered drum. With this apparatus, the irritability and response of both muscle and nerve to electrical stimulation may be studied. The reactions of the muscles of cold-blooded animals are much like those of man, as has been demonstrated by studies in metabolism.

In the contraction of muscle, three phases are noticed. When the electrical contact establishing a current is made, at first nothing seems to happen. Then the muscle suddenly thickens and shortens. Following this, relaxation occurs with the muscle returning to its

previous condition. The first period is called "latent," the second, contractile, and the third, relaxation.

The speed with which contraction occurs varies. For a slow contraction, more energy is used and more work is done than in a rapid contraction. It is said frog's muscles contract ten times as rapidly as do those of man. Possibly, the rate varies according to the size of the individual, the larger moving the more slowly.

At higher temperatures, muscle reaction is quickened, with a hastening of the chemical changes. Cold lengthens the latent period, and prolongs the contraction. These slower contractions mean greater efficiency.

Up to a certain point, the more resistance is given to a muscle, or the greater its load, the stronger is its contraction. Passing that point, increases in the load lessens the power and work done.

Muscle Fatigue.—As a muscle is stimulated again and again, the recording apparatus for a "muscle-nerve preparation" shows at first an increasing vigor of contraction. Presently this changes, and the muscle record becomes lower and lower, finally becoming lost. The muscle is exhausted. It may be said that the first lowering of the contraction curve indicates a fatigue from which the muscle can recover by resting. The exhausted muscle cannot do much work even after resting. It is necessary to pass fresh blood or normal saline solution through it, or expose it to oxygen. Then it will go on contracting as before. The process may be repeated many times. Fatigue was caused by using up the material that supplies the energy of the muscle, and by the accumulation of waste. The waste was washed out by the saline solution.

Tetanus.—The rapid repetition of nervous stimuli produces a practically continuous contraction, during which there is no time for the relaxation of the muscle. A sustained effort of the will in holding a muscle contracted implies a long series of efferent impulses following each other without pause. This is a tetanic contraction.

Chemical Changes in Muscle.—During muscular contraction a greater amount of O is absorbed by the muscle plasma, and an increased quantity of CO_2 is given off.

The presence of an excess of lactic acid in the working muscle is responsible for its fatigue. In a fresh muscle it amounts to only a trace. This increase of lactic acid is associated with a decrease of the contained glycogen. There is no definite change in the fats or proteins, but the one definite assertion that can be made is that glycogen has been converted into lactic acid during muscular contraction.

If the exhausted muscle is exposed to oxygen, the lactic acid disappears. It has been suggested that the oxygen may convert part of the lactic acid into glycogen, which can be used again and again for further contractions.

In studying these reactions, tests in metabolism by the observation of continued muscular work throw light on the subject. A single twitch from a single electrical contact gives little information in regard to the chemical and thermal changes in muscle.

By very delicate instruments, the heat produced in one twitch of a frog's muscle can be measured. It can be inferred that as the absorption or production of heat is always associated with chemical reactions, there must be chemical changes in one muscular twitch. Heat production in these muscles follows excitation, with a smaller amount produced during relaxation. The first accession of heat is due to the conversion of glycogen into lactic acid. The second accession of heat is due to the neutralization of lactic acid mainly by the alkali proteins in the muscle substance.

When a muscle contracts under airless conditions, the formation of 1 gm. of lactic acid releases 370 heat calories.

Since the energy of the body comes from the oxidation of the foodstuffs, the examination of the waste products resulting from such oxidation, the urine, feces, CO_2, considered with the amount of oxygen taken in, during a given period, will indicate the total oxidation taking place in the body. By comparing the oxidation resulting from a person absolutely quiescent, with the oxidation of the same person taking vigorous or even violent exercise, some idea of the amount of chemical change in the body muscles may be obtained.

Prolonged exercise depletes the carbohydrates of the body, showing that while the proteins are not soon affected, there is a very great increase in the respiratory exchange of O and CO_2. The energy of muscular contraction is derived from the glycogen breaking down into lactic acid, followed by the oxidation of lactic acid into CO_2 and water.

HOW TO STUDY THE MUSCLES.

If the conformation of the bones has already been fixed in the mind's eye, by actual use of the bones during the study of the osseous system, the study of muscles is rendered easier. After learning the attachments of muscles, and finding the bony markings, paper or cloth patterns cut out in the size and shape of the muscles, and applied to the skeleton, give a vivid idea of reality. The use of rubber bands or strings attached to the skeleton and made to imitate the muscular pull is also recommended. The skeleton is not always available for study, but our own bodies are. The contraction of most of the superficial muscles can easily be felt. Continued observation of the contracting areas will help greatly in this study.

The Naming of Muscles.—There are various considerations entering into the nomenclature of muscles, as action, shape, location, relative size, attachments, direction of fibers, etc. For instance,

pronator teres indicates both the action as a pronator of the forearm and its round shape as distinguished from the quadratus or square pronator. The *pectoralis major* indicates the location on the chest wall, and the greater size of this muscle as compared with the minor pectoral. The prefix *flexor, extensor, pronator, supinator, adductor,* or *abductor,* to their names indicate the principal action of the muscle. The *brachio-radialis* indicates the bones to which the muscle is attached, the *obliquus externus abdominis* indicates the oblique direction of the fibers, as well as its external position on the abdominal wall, as compared with the interior position of the *obliquus internus abdominis.* Attention to these names and their meanings will help to fix the actions of the various muscles in the memory. All muscles are given Latin names, so making them intelligible to scientific students everywhere

MOVEMENTS PRODUCED BY MUSCLES.

The movements produced by muscles always involve several acting together, with still others holding firm the points of origin, while others control the speed and range of the movement. In studying the action, then, of any particular muscle, there must also be included the consideration of the antagonistic and the fixator muscles. The "actions" given in the text refer to those taken in the "anatomical position," and their isolated actions supposing one muscle *could act alone.* It must be remembered that gravity modifies the action of the antagonistic muscles as well as that of the fixators. In seeking means for training very weak muscles, gravity may either increase or lessen the resistance to their action. For example, there is a great difference in the action of the gastrocnemius in raising the weight of the body, and what it needs to do in extending the foot when one is lying on the side. The latter may be called the minimal contraction.

By offering resistance to the action of a muscle, its maximal contraction can be obtained.

The movement of *flexion* is produced by *flexor* muscles, with the opposite movement of *extension* produced by *extensor* muscles. *Abductor* muscles oppose *adductors,* and *pronators* oppose *supinators. Inward rotators* oppose *outward rotators.* The movement of circumduction is a combination of flexion, extension, abduction, and adduction. It may vary in direction, inward or outward. Muscles are not named as producing this movement.

MOVEMENTS OF THE SEGMENTS OF THE UPPER EXTREMITY.

Attention is called to the fact that in describing movements or positions the body is supposed to be standing erect, with arms hanging at the sides with the palms facing forward. (Figs. 2 and 3.)

The *shoulder-girdle* moves upward, downward, forward, and backward, upon the articulation of the clavicle with the sternum. To indicate these movements, the terms *elevation, depression, abduction* and *adduction* are used.

The *arm* moving at the shoulder-joint is raised forward in *flexion,* backward in *extension,* outward in *abduction,* and inward in *adduc-*

Fig. 124.—Comparison of shoulders and arms in different attitudes. The sliding outward of the scapula when the arm is raised is very marked. (Gerrish.)

tion. It is turned *inward* or *outward* in *rotation* and in *circumduction.*

The *forearm* moving at the elbow-joint is raised forward in *flexion,* and returns to the straight line in *extension.* At the upper radio-ulnar joint, the forearm turns inward in *pronation,* outward in *supination.*

The *hand* at the wrist moves forward in flexion, backward in extension, outward in abduction, and inward in adduction, while circumduction may be inward or outward. The *fingers* moving forward at the various phalangeal joints are in flexion, while the opposite movement is extension. This is true at the metacarpo-phalangeal joints, also, at which abduction and adduction occur from and toward the middle line of the second finger.

The *thumb* bends toward the little finger in flexion, crossing the palm, and the reverse in extension. This is on account of the forward position of the first metacarpal bone, with the thumb almost at a right angle with the fingers. Abduction of the thumb is outward, while adduction is in the opposite direction.

In these movements of the upper extremity, flexion is movement forward. In the lower extremity, in the successive joints, flexion and extension alternate in the forward direction. The explanation lies in their different functions, prehension in the upper and locomotion and balance in the lower members.

(It should be noted that all the joints of the body when at rest are in a position midway between flexion and extension, or whatever other position is allowed.)

THE MUSCLES MOVING THE SHOULDER.

Upward and backward.	*Downward and forward.*
Trapezius	Serratus magnus
Levator scapulæ	Pectoralis minor
Rhomboideus minor and major	Subclavius

Trapezius.—In three parts. (Fig. 125.)

Location.—Superficial on upper back and shoulder.

Origin.—Superior curved line and external protuberance of occiput; ligamentum nuchæ; spines of seventh cervical and twelve thoracic vertebræ.

Insertion.—Outer third of posterior border of clavicle. Inner border of acromion and upper border of spine of scapula. Tubercle of spine near its inner end.

Nerve Supply.—Spinal accessory and third and fourth cervical.

Action.—With head fixed, upper fibers lift outer end of clavicle with scapula. With scapula fixed, one side rotates the head; both sides pull the head backward.

Middle fibers, lift acromion when bearing weight on shoulders; adduct scapula.

Lower fibers, pull vertebral border of scapula down and in. As a whole, rotates scapula to turn the glenoid fossa upward and outward.

Levator Scapulæ.—(O. T. levator anguli scapulæ). (Fig. 126.)

Location.—On the side of the neck, under the trapezius.

Origin.—Upper four or five cervical vertebræ, on transverse processes.

Insertion.—Vertebral border of scapula from superior angle to root of spine.

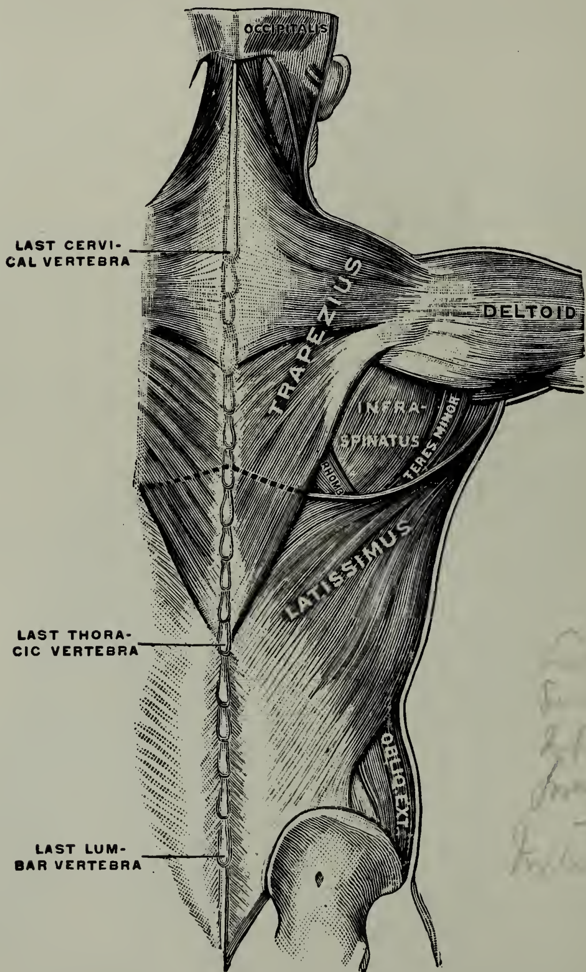


FIG. 125.—Muscles in the superficial layer of the back. (Testut.)

Nerve Supply.—Third, fourth and fifth cervical.

Action.—Lifting upper angle of scapula with depression of the outer end.

Rhomboideus Minor. (Fig. 126.)

Location.—Between the scapula and spine, underneath the trapezius.

Origin.—Ligamentum nuchæ; spines of seventh cervical and first thoracic vertebræ.
Insertion.—Vertebral border of scapula at root of spine.

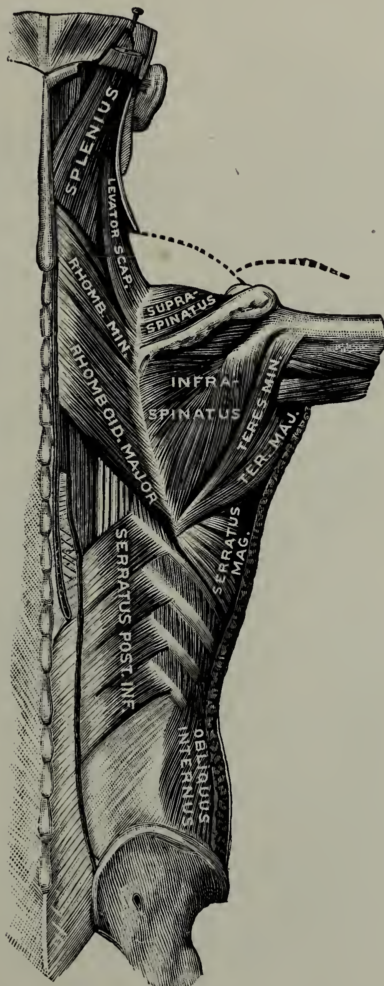


Fig. 126.—Muscles in the second layer of the back and on the dorsum of the shoulder. (Testut.)

Nerve Supply.—Fifth cervical.
Action.—Adducts and elevates the scapula, with some rotation.

Rhomboideus Major. (Fig. 126.)
Location.—Just below the minor.

Origin.—Spines of the upper four or five thoracic vertebræ.
Insertion.—Vertebral border of scapula, below that of the minor.
Nerve Supply.—Fifth cervical.
Action.—Adducts and elevates the scapula.

FIG. 127.—Serratus magnus of right side. The scapula has been turned backward and drawn outward. (Modified from Testut.)

Serratus Magnus.—(Fig. 127.)

Location.—Anterior to the scapula on the upper side of the chest.

Origin.—By digitations, in three parts.

Upper part, from first and second ribs, several inches from their costal cartilages.

Middle part, from second and third ribs.
Lower part, from fourth to eighth ribs.

Insertion.—Upper part to ventral border of the superior angle.
Middle part to ventral surface of vertebral border, except angles.
Lower part to ventral border of the lower angle.

Nerve Supply.—Posterior thoracic.

Action.—The upper and middle parts draw the shoulder forward as in pushing, while the lower part rotates the scapula, turning the glenoid fossa upward as in raising the arm. It assists the deltoideus in elevating the arm by fixing the scapula, so steadying the glenoid fossa. Possibly, with the shoulder fixed, the serratus may help in raising the ribs in inspiration.

Fig. 128.—Pectoralis minor of right side. (Testut.)

Pectoralis Minor. (Fig. 128.)

Location.—On the front wall of the chest, covered by the large pectoral.

Origin.—Third, fourth and fifth ribs, near their cartilages.

Insertion.—Coracoid process of the scapula.

Nerve Supply.—Internal anterior thoracic.

Action.—When chest is fixed, draws scapula down and forward. When scapula is fixed, draws the chest upward, as in forced inspiration.

Subclavius. (Fig. 128.)

Location.—Under the clavicle.
Origin.—The first rib and its cartilage.
Insertion.—A groove on the under surface of the clavicle.
Nerve Supply.—Fifth and sixth cervical.
Action.—Depresses the scapula and turns the glenoid fossa downward.

THE MUSCLES MOVING THE ARM.

(See Figs. 176 to 183, pages 222 to 225.)

Abductors.	*Adductors.*
Deltoideus	Pectoralis major, Coracobrachialis } also flexors
Supraspinatus	Latissimus, Teres major } also extensors

Outward rotators.	*Inward rotator.*
Infraspinatus	Subscapularis
Teres minor	

Deltoideus. (Fig. 129.)

Location.—Forming a cap over the shoulder-joint.
Origin.—Anterior border of the outer third of the clavicle. Acromion process, and lower border of the spine of the scapula.
Insertion.—The deltoid impression, midway of the outer surface of the humerus.
Nerve Supply.—The circumflex.
Action.—Abduction of the arm. The anterior fibers carry the arm forward, the posterior fibers carry it backward.

Supraspinatus. (Fig. 130.)

Location.—In the supraspinous fossa, covered by the trapezius.
Origin.—Inner two-thirds of supraspinous fossa.
Insertion.—The uppermost facet on the greater tuberosity of the humerus.
Nerve Supply.—The suprascapular.
Action.—Abducts the arm.

Pectoralis Major. (Fig. 129.)

Location.—Covers the front wall of the chest.
Origin.—The inner half of the anterior border of the clavicle. The anterior surface of the sternum. The cartilages of the upper six ribs.
Insertion.—The outer lip of the bicipital groove of the humerus.

Nerve Supply.—Internal and external anterior thoracic.
Action.—Sternal portion helps to flex the arm. All portions draw the arm across the chest. When the arms are fixed, it helps the latissimus to raise the trunk. With the pectoralis minor and subclavius it acts upon the ribs to elevate them, as in forced inspiration.

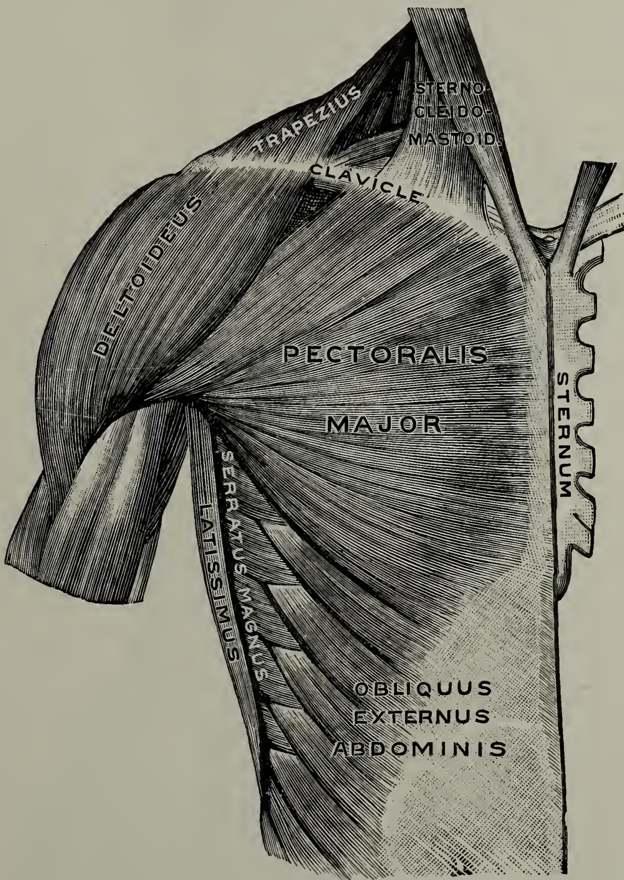


FIG. 129.—Front of chest and shoulder of right side, superficial muscles. (Testut.)

Coracobrachialis. (Figs. 131, 132.)
Location.—On the inner side of the upper part of the arm.
Origin.—The coracoid process of the scapula.
Insertion.—The middle of the inner border of the humerus.
Nerve Supply.—The musculocutaneous.
Action.—Flexion and adduction of the arm.

11

Latissimus.—(O. T. latissimus dorsi). (Fig. 125.)

Location.—The lower part of the back and the axilla.

Origin.—Spines of six lower thoracic, all the lumbar, and sacral spines. The lumbar fascia; the outer lip of the iliac crest, hind part. The three or four lower ribs, and the lower angle of the scapula.

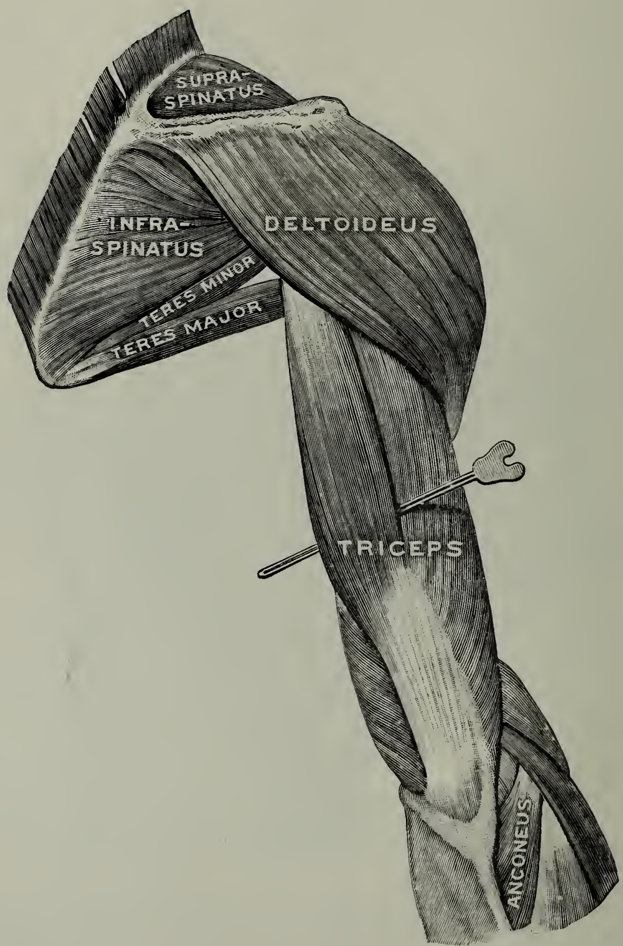


FIG. 130.—Muscles on the dorsum of the right shoulder and arm. (Testut.)

Insertion.—The inner lip and floor of the bicipital groove of the humerus.

Nerve Supply.—Long subscapular.

Action.—Extension, adduction and inward rotation of the arm.

Teres Major. (Fig. 126.)

Location.—In the posterior wall of the axilla.

Origin.—The dorsal surface of the axillary border of the scapula, lower half.

FIG. 131.—Muscles of the front of the right shoulder and arm. (Testut.)

Insertion.—The inner lip of the bicipital groove of the humerus.

Nerve Supply.—Lower subscapular.

Action.—Helps the latissimus in extension, adduction and inward rotation of the arm.

Infraspinatus. (Fig. 126.)

Location.—On the back of the scapula, partly covered by the trapezius.

Origin.—Infraspinous fossa, inner two-thirds.

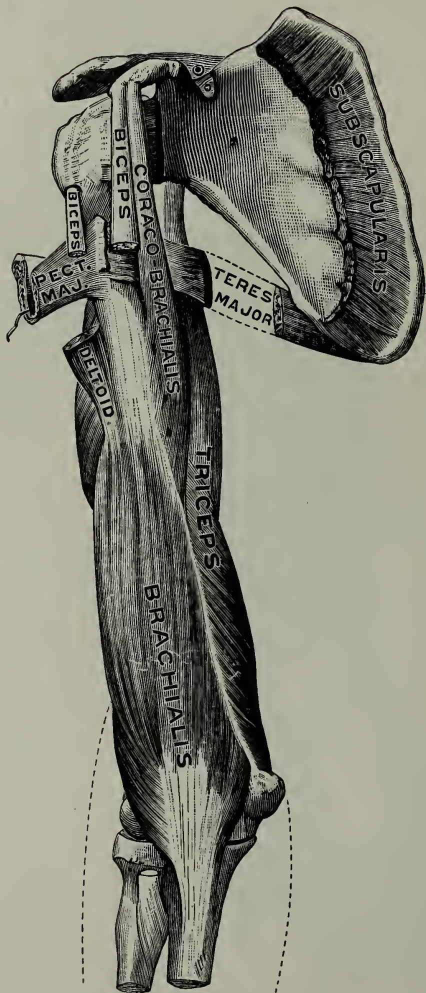


Fig. 132.—Muscles of the right arm, front view, the biceps having been removed. (Testut.)

Insertion.—Middle facet on the greater tuberosity of the humerus.

Nerve Supply.—Suprascapular.

Action.—Rotates the arm outward.

Teres Minor. (Fig. 126.)

Location.—In the posterior wall of the axilla.

Origin.—Dorsal surface of axillary border of the scapula, upper half.

Insertion.—The lowermost facet on the greater tuberosity of the humerus.

Nerve Supply.—Circumflex.

Action.—Rotates the arm outward.

Subscapularis. (Fig. 127.)

Location.—The under surface of the scapula, next the chest wall.

Origin.—The ventral surface of the scapula, in the subscapular fossa.

Insertion.—The lesser tuberosity of the humerus.

Nerve Supply.—Upper and lower subscapular.

Action.—Rotates the arm inward.

THE MUSCLES MOVING THE FOREARM.

(See Figs. 176 to 183, pages 222 to 225.)

Flexors.	*Extensors.*
Biceps flexor cubiti	Triceps extensor cubiti
Brachialis	Anconeus
Brachio-radialis	

Biceps Flexor Cubiti. (Fig. 131.)

Location.—On the front of the arm, superficial.

Origin.—Long head, the upper border of the glenoid fossa. Short head, the coracoid process of the scapula.

Insertion.—The bicipital tuberosity of the radius.

Nerve Supply.—The musculocutaneous.

Action.—Flexes the forearm. The long head acts to flex the arm at the shoulder-joint. If the hand is pronated, the biceps supinates it. With the forearm in supination, it is more easily flexed by the biceps.

Brachialis.—(O. T. brachialis anticus or anterior). (Fig. 132.)

Location.—The lower front of the arm, deeply placed.

Origin.—The lower half of the ventral surface of the humerus, embracing the insertion of the deltoideus.

Insertion.—The coronoid process of the ulna.

Nerve Supply.—Musculocutaneous, and to some degree, the musculospiral.

Action.—Flexes the forearm.

Brachio-radialis.—(O. T. supinator longus). (Figs. 133, 134.)

Location.—The outer side of the forearm, superficial.

Origin.—Upper two-thirds of the external supracondylar ridge of the humerus.

Insertion.—The styloid process of the radius.

Fig. 133.—Superficial muscles of front of right forearm. (Testut.)

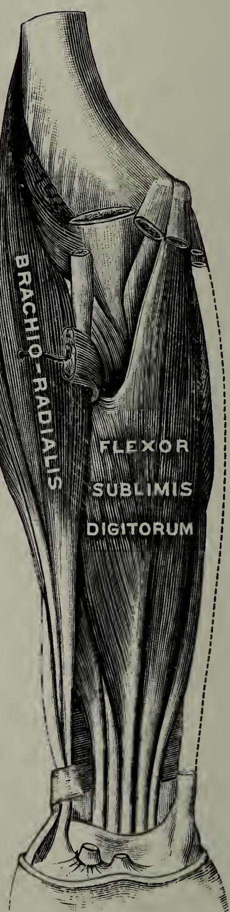


Fig. 134.—Flexor sublimis digitorum of right side. (Testut.)

Nerve Supply.—Musculospiral.

Action.—Flexion of the forearm, especially in the position midway between pronation and supination.

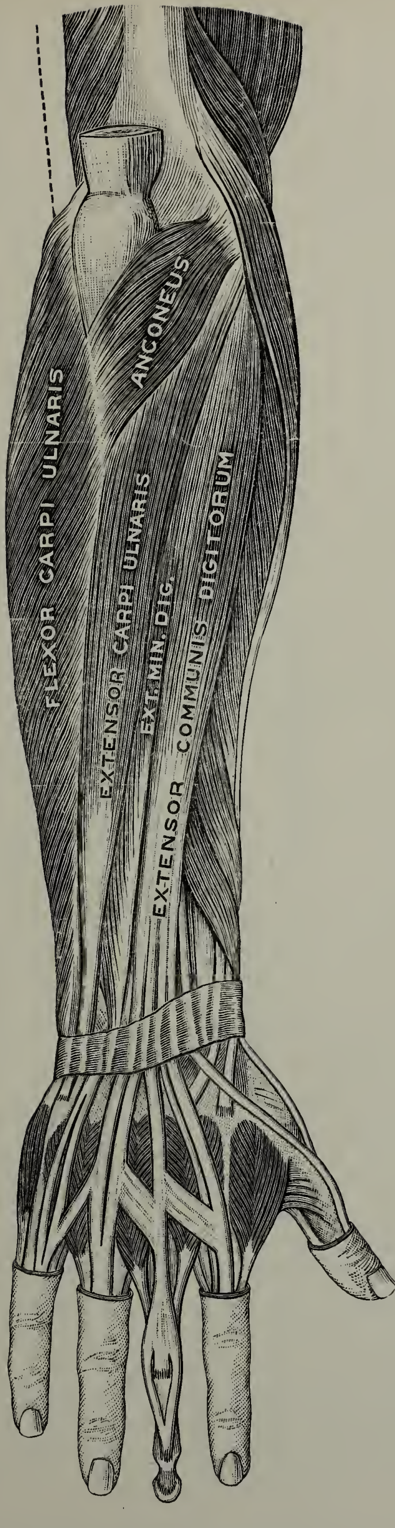


Fig. 135.—Muscles in the dorsum of the right forearm and hand. (Testut.)

Triceps Extensor Cubiti. (Fig. 130.)

Location.—On the back of the arm.

Origin.—Long head, the lower border of the glenoid fossa.

Inner head, the posterior surface of the humerus, below the musculospiral groove.

Outer head, the posterior surface of the humerus, above the musculospiral groove.

Insertion.—The back of the upper part of the olecranon process of the ulna.

Nerve Supply.—Musculospiral.

Action.—Extends the forearm. The long head extends the arm, acting with the latissimus.

Anconeus. (Figs. 130, 135.)

Location.—Back and outer side of the elbow-joint.

Origin.—The external condyle of the humerus.

Insertion.—Outer side of olecranon process and upper dorsal surface of ulna.

Nerve Supply.—Musculospiral.

Action.—A helper of the triceps in extending the forearm.

THE MUSCLES MOVING THE OUTER PART OF THE FOREARM.

Pronators.	*Supinator.*
Pronator teres	Supinator
Pronator quadratus	

Pronator Teres.—(O. T. pronator radii teres). (Fig. 133.)

Location.—Crosses over the front of the forearm, from inner side, outward.

Origin.—The inner condyle of the humerus.

Insertion.—The middle of the outer surface of the shaft of the radius.

Nerve Supply.—The median.

Action.—Pronation of the hand, and if that is prevented, flexion of the forearm.

Pronator Quadratus. (Fig. 136.)

Location.—Deep in the lower part of the front of the forearm.

Origin.—The lower fourth of the anterior surface of the ulna.

Insertion.—The lower fourth of the anterior surface of the radius.

Nerve Supply.—Anterior interosseous branch of the median.

Action.—Pronates the hand, turning the radius over the ulna.

Supinator.—(O. T. supinator brevis). (Fig. 136.)

Location.—Deep in the upper third of the outer part of the forearm.

Origin.—The external condyle of the humerus; the triangular area below the lesser sigmoid cavity of the ulna.

Insertion.—The back of the neck of the radius, and the posterior, outer surface of the same above the oblique line.

Nerve Supply.—Posterior interosseous division of the musculospiral.

Action.—Supinates the forearm, assisting the brachio-radialis, and serving as a supplementary ligament to the elbow-joint.

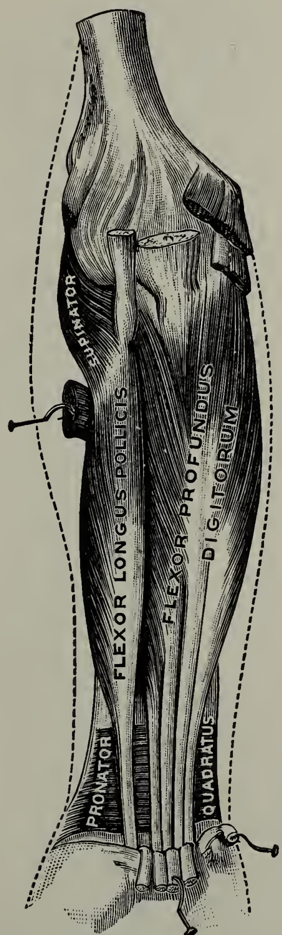


Fig. 136.—Muscles in the right forearm, the deepest layer. (Testut.)

THE MUSCLES MOVING THE WHOLE HAND.

(See Figs. 176 to 183, pages 222 to 225.)

Flexors.	*Extensors.*
Flexor carpi radialis	Extensor carpi radialis longus
(Flexor) palmaris longus	Extensor carpi radialis brevis
Flexor carpi ulnaris	Extensor carpi ulnaris

The *extensor* muscles of the forearm and the *supinator* may be remembered as coming from the *external* condyle of the humerus or just above it. The *flexor* and *pronator* muscles come from the internal condyle, and are associated in action. Note the greater ease in piano playing, of running from the little finger to the thumb, than in the reverse direction.

The movements at the wrist, besides flexion and extension are adduction and abduction, which are performed by the combined action of a flexor and extensor, on the ulnar and radial sides respectively.

Flexor Carpi Radialis. (Fig. 133.)

Location.—Superficial on the front of the forearm, crossing diagonally.

Origin.—Inner condyle of the humerus.

Insertion.—The base of the second metacarpal bone, on its palmar aspect.

Nerve Supply.—The median.

Action.—Flexion on radial side, and pronation of hand. Helps the radial extensor to abduct the hand.

Palmaris Longus. (Fig. 133.)—A very small muscle, with a long tendon, coming from the internal condyle to the palmar fascia, which it makes tense. Does a little toward flexion. This muscle is quite frequently lacking.

Flexor Carpi Ulnaris. (Figs. 133, 135.)

Location.—On the front and inner aspect of the forearm.

Origin.—Inner condyle of the humerus.

Inner side of the olecranon process and the common aponeurosis on the dorsal border of the ulna, from which proceeds also the extensor carpi ulnaris and the flexor profundus digitorum.

Insertion.—The pisiform, unciform and the base of the fifth metacarpal on the palmar aspect.

Nerve Supply.—Ulnar.

Action.—Flexes the hand on the ulnar side. Helps the ulnar extensor to adduct the hand.

Extensor Carpi Radialis Longus. (Fig. 137.)

Location.—On the outer border of the forearm.

Origin.—The lower part of the external supracondylar ridge of the humerus.

Insertion.—The base of the metacarpal of the first finger, posteriorly.

Nerve Supply.—Musculospiral.

Action.—Extends the hand on radial side. Helps the radial flexor to abduct the hand.

Extensor Carpi Radialis Brevis. (Fig. 137.)

Location.—The outer part of the forearm, posteriorly.

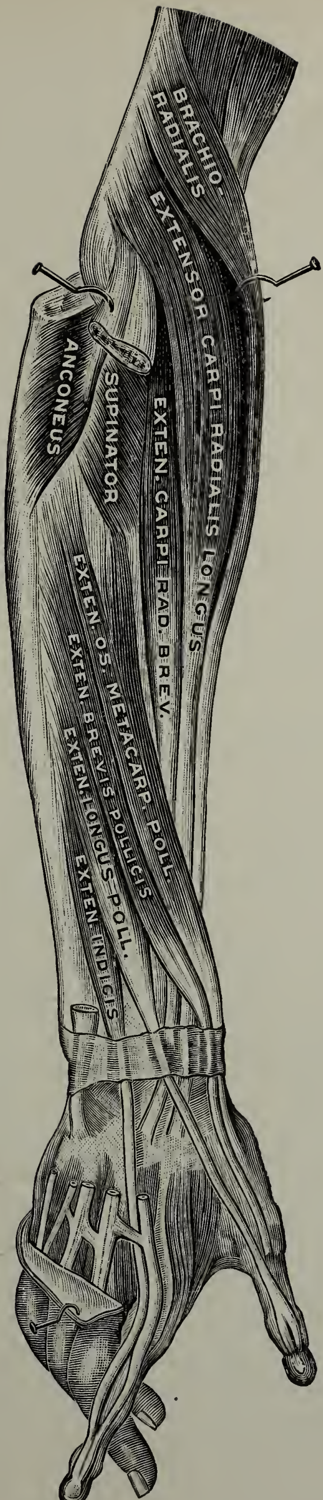


Fig. 137.—Muscles in radial region of right forearm, and deep muscles in its dorsum. (Testut.)

Origin.—The external condyle of the humerus.
Insertion.—The base of the metacarpal of the second finger, posteriorly.
Nerve Supply.—Posterior interosseous branch of the musculo-spiral.
Action.—Extends the hand on the radial side.

Extensor Carpi Ulnaris. (Fig. 135.)
Location.—On the ulnar side of the back of the forearm.
Origin.—External condyle of the humerus and posterior border of the ulna.
Insertion.—Base of the fifth metacarpal bone, on its posterior aspect.
Nerve Supply.—Posterior interosseous branch of the musculo-spiral.
Action.—Extends the hand on the ulnar side, and with the ulnar flexor, adducts the hand.

Note that the "carpi" muscles are inserted into the metacarpal bones but move the wrist-joint.

Note that all the extensor muscles are supplied by the musculo-spiral nerve.

THE MUSCLES MOVING THE FINGERS.

Flexors.	*Extensors.*
Flexor sublimis digitorum	Extensor communis digitorum
Flexor profundus digitorum	Extensor minimi digiti
*Flexor ossis metacarpi minimi digiti	Extensor indicis
*Flexor brevis minimi digiti	
*Lumbricales	

* These muscles are situated entirely in the hand.

Flexor Sublimis Digitorum. (Fig. 134.)
Location.—On the front of the forearm, and in the palm of the hand.
Origin.—The internal condyle of the humerus.
The coronoid process of the ulna, and the oblique line of the radius.
Insertion.—The sides of the base of the second phalanx of the four fingers. Above the wrist, the tendon divides into four parts, which pass under the annular ligament, through the palm of the hand, and on to the base of the second phalanx of each finger, where the tendons divide, going to each side of the bone, and leaving a slit through which the tendon of the deep flexor has to pass to get to the base of the third phalanx.
Nerve Supply.—The median.

Action.—Flexes the second phalanx of each of the fingers. Continuing to contract, it flexes secondarily, the first phalanx.

Flexor Profundus Digitorum. (Figs. 136 and 138.)

Location.—Deep in the front of the forearm, next the bone, and in the hand.

Origin.—The upper three-fourths of the ventral surface of the ulna.

The adjacent interosseous membrane.

The posterior border of the ulna, in common with the extensor carpi ulnaris, and the flexor carpi ulnaris.

Insertion.—The base of the third phalanx of the four fingers.

Above the wrist the tendon divides into four slips, which pass into the hand, under those of the superficial flexor, and go up through the slit in the latter tendon to the distal phalanx.

Nerve Supply.—Ulnar and anterior interosseous branch of the median.

Action.—Flexes the third phalanx of the four fingers.

Fig. 138.—Tendon of flexor profundus perforating tendon of flexor sublimis. (Testut.)

Flexor Ossis Metacarpi Minimi Digiti. (Fig. 139.) (O. T. Opponens minimi digiti.)—A small muscle deep in the hypothenar eminence, whose action draws the ulnar side of the hand outward, deepening the palm. It originates on the unciform process of the unciform bone, and passes to the ulnar margin of the metacarpal of the little finger.

Flexor Brevis Minimi Digiti. (Fig. 139.)

Location.—In the palm of the hand, on the ulnar side, subcutaneous.

Origin.—Unciform process of the unciform bone and the annular ligament.

Insertion.—Base of the first phalanx of the little finger.

Nerve Supply.—Ulnar.

Action.—Flexes the first phalanx of the little finger.

Lumbricales. (Figs. 139, 140.)—Four small muscles pass from the tendons of the flexor profundus digitorum to those of the extensor communis digitorum. They are small, and so-called from their

Fig. 139.—Muscles of the right palm. The abductors of the thumb and little finger have been removed. (Testut.)

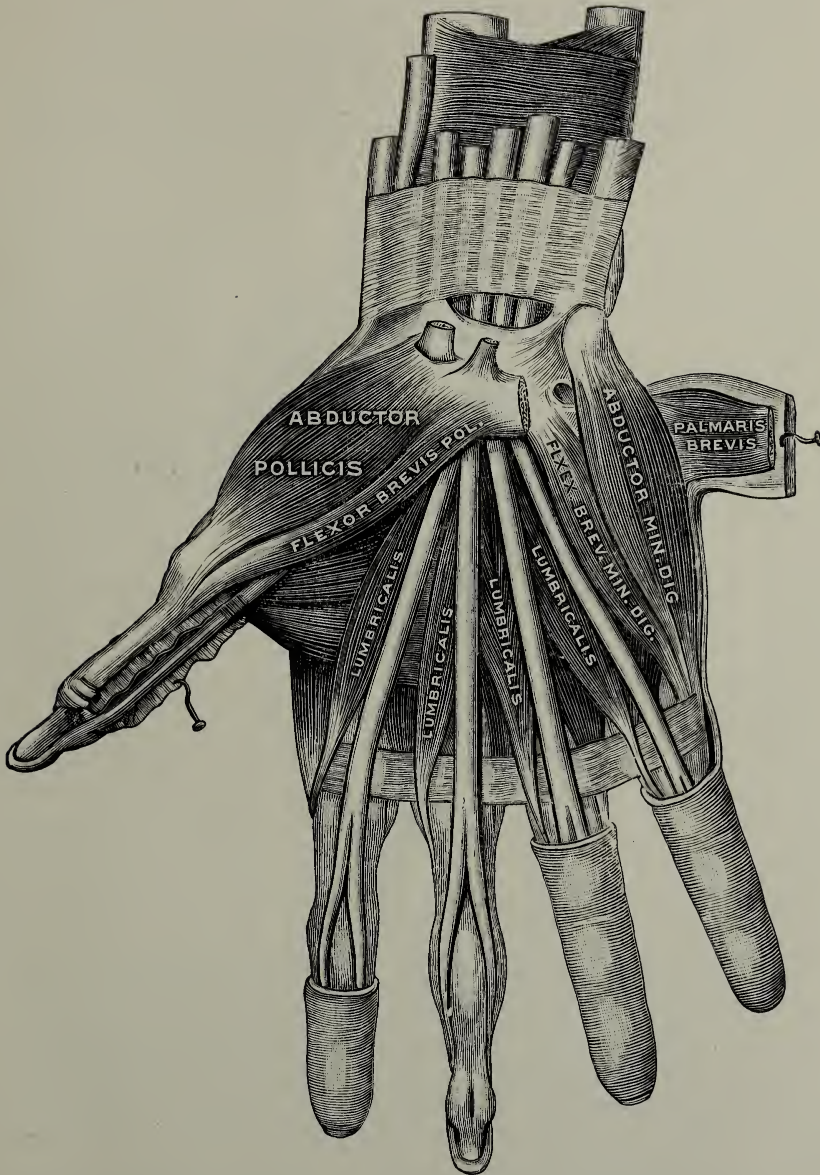


FIG. 140.—Muscles of the right palm. The palmaris brevis is reflected to the ulnar side. (Testut.)

resemblance to earth worms. They flex the first phalanx of the fingers, and extend the second and third.

Extensor Communis Digitorum. (Fig. 135.)

Location.—On the back of the forearm and hand, superficial.

Origin.—The external condyle of the humerus.

Insertion.—The base of the second and third phalanges of each finger. Above the wrist, the tendon divides into four slips,

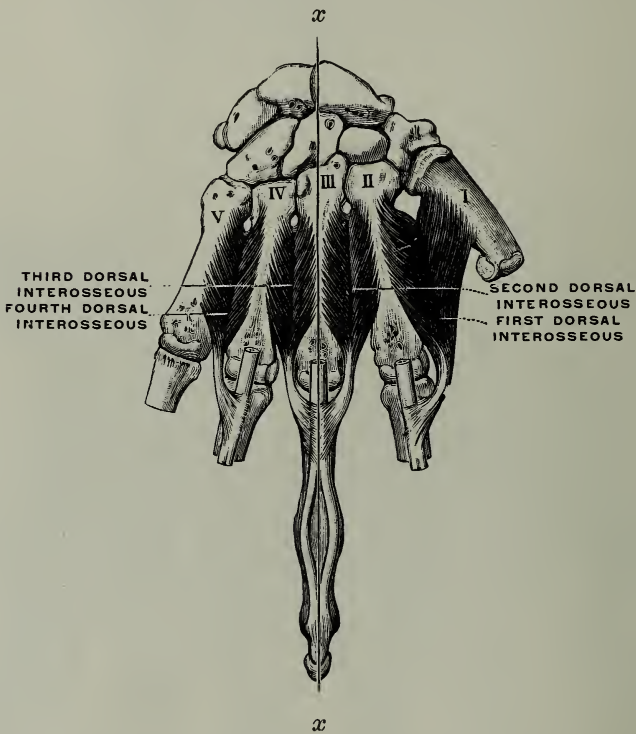


Fig. 141.—Interossei dorsales of right hand. The line $x\ x$ is that from which abduction is made. (Testut.)

which pass under the annular ligament, and then to the fingers. Each slip divides into three parts, the middle one attaching to the base of the second phalanx and the other two uniting to be attached to the base of the third phalanx of the fingers. The name "communis" refers to the fact that the tendinous attachment is to the two phalanges by a common tendon.

Nerve Supply.—Posterior interosseous branch of the musculospiral.

Action.—Extends the second and third phalanges of the fingers.

Extensor Minimi Digiti. (Fig. 135.)

Location.—In the back of the forearm and hand.

Origin.—External condyle of the humerus.

Insertion.—Second and third phalanges of the little finger.

Nerve Supply.—Posterior interosseous branch of the musculo-spiral.

Action.—Extends the second and third phalanges of the little finger.

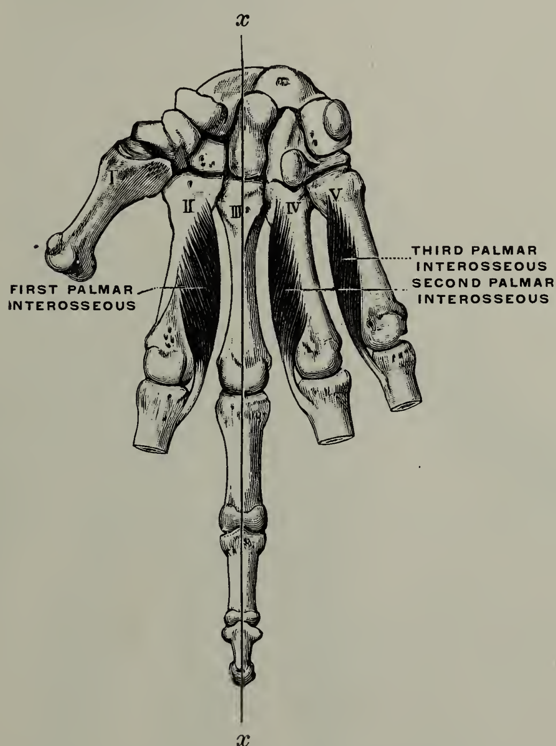


Fig. 142.—Interossei palmares of right hand. The line x x is that to which adduction is made. (Testut.)

Extensor Indicis. (Fig. 137.)

Location.—In the back of forearm and hand.

Origin.—Lower part of the dorsal surface of the ulna and interosseous membrane.

Insertion.—The first tendon of the extensor communis digitorum.

Nerve Supply.—Posterior interosseous branch of the musculo-spiral.

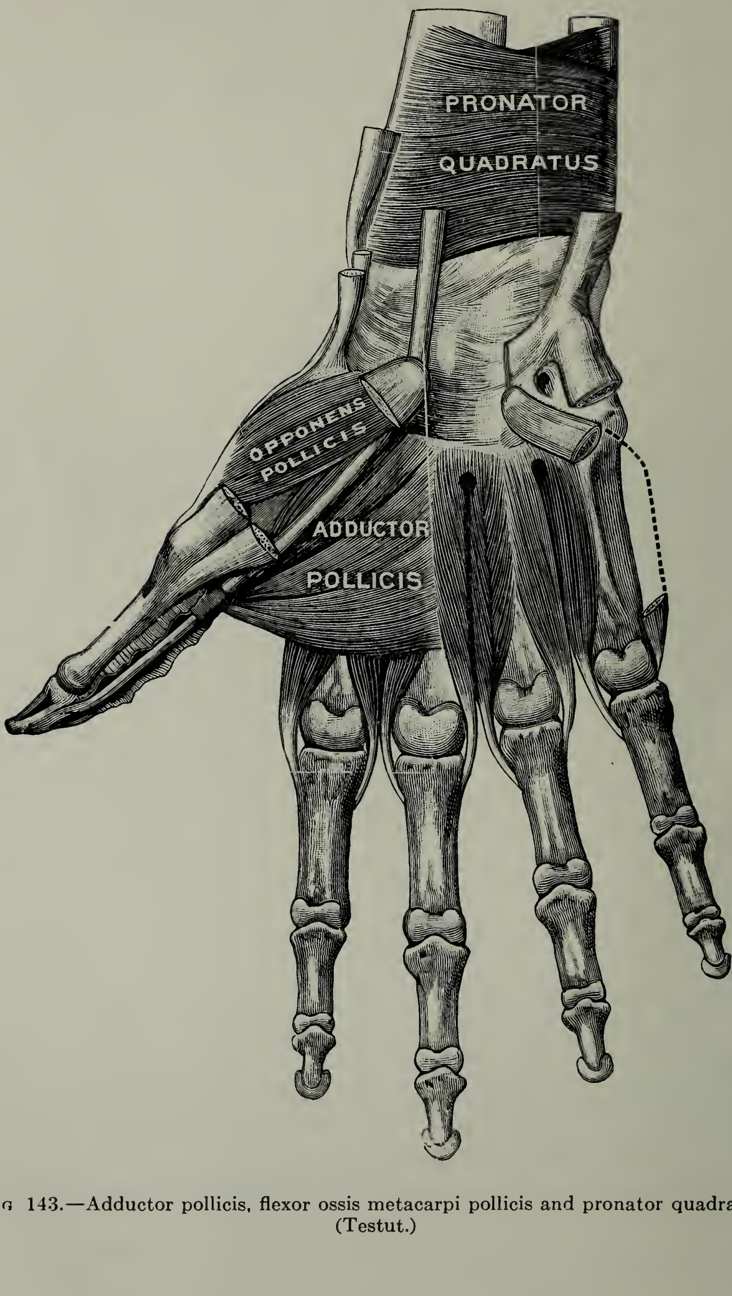


FIG 143.—Adductor pollicis, flexor ossis metacarpi pollicis and pronator quadratus. (Testut.)

Action.—Independent extension of the first finger, and slight adduction. (NOTE that while the extensor communis digitorum extends the four fingers, the first and fourth fingers have additional extensors that extend them even when the middle two fingers are flexed.)

Abductors and Adductors of the Fingers. (Figs. 140, 141, 142.)—The fingers are abducted from the line passing through the second finger by four small muscles, the *interossei dorsales.* These originate from the contiguous sides of the five metacarpal bones, and the tendons are inserted on the first phalanges so that the first and second pull the first and second fingers from the central line. The third and fourth pull the second and third fingers from the central line. When the second tendon pulls the second finger toward the thumb side, it is adducted by the tendon attached on the ulnar side of this finger, and a similar condition results when the third tendon pulls the second finger toward the ulnar side. The second and third interossei dorsales muscles therefore act as abductors and adductors.

The *interossei palmares,* coming from the second, fourth and fifth metacarpal bones, are inserted into the bases of the corresponding fingers, and adduct them toward the line passing through the middle of the second finger.

The little finger has a special abductor, on the palmar surface, coming from the pisiform bone to the base of the first phalanx of the little finger. These muscles are all supplied by the ulnar nerve.

THE MUSCLES MOVING THE THUMB AND ITS METARCARPAL BONE.

Flexors.	*Extensors.*
*Flexor ossis metacarpi pollicis	Extensor ossis metacarpi pollicis
*Flexor brevis pollicis	Extensor brevis pollicis
Flexor longus pollicis	Extensor longus pollicis

Abductor.	*Adductor.*
*Abductor pollicis	*Adductor pollicis

* Entirely in the hand.

Flexor Ossis Metacarpi Pollicis.—(O. T. Opponens pollicis.) (Figs. 139, 140.)

Location.—Deep in the thenar eminence. (Thenar eminence, the ball of the thumb.)

Origin.—Trapezium and annular ligament, on the palmar aspect.

Insertion.—Shaft of the first metacarpal bone, on the front of the radial side.

Nerve Supply.—Median.

Action.—Flexes and rotates the first metacarpal inward.

Flexor Brevis Pollicis. (Fig. 139.)
Location.—Deep in the ball of the thumb.
Origin.—Trapezium and annular ligament on the radial side, palmar aspect. Upper part of the first metacarpal on the ulnar side.
Insertion.—First part, outer side of the base of the first phalanx of the thumb, with the abductor pollicis.
Second part, inner side of the base of the first phalanx of the thumb, with the adductor pollicis.
With each of these tendons there is a small sesamoid bone.
Nerve Supply.—The first part, the median; second part, the ulnar.
Action.—Flexes the first phalanx of the thumb.

Flexor Longus Pollicis. (Fig. 136.)
Location.—Front part of forearm and palmar aspect of the thumb.
Origin.—Oblique line of radius, and middle two-thirds of shaft and interosseous membrane adjoining.
Insertion.—Base of second phalanx of the thumb, palmar aspect.
Nerve Supply.—Anterior interosseous branch of the median.
Action.—Flexes the second phalanx of the thumb.

Extensor Ossis Metacarpi Pollicis.—(O. T. Abductor longus pollicis.) (Fig. 137.)
Location.—Deep in the lower part of the back of the forearm.
Origin.—The posterior aspect of the shaft of the radius and ulna, with the interosseous membrane between.
Insertion.—Base of the first metacarpal bone, dorsally.
Nerve Supply.—Posterior interosseous branch of the musculospiral.
Action.—Extends and abducts the first metacarpal bone.

Extensor Brevis Pollicis.—(O. T. Extensor primi internodii pollicis.) (Fig. 137.)
Location.—Deep in the lower part of the back of the forearm.
Origin.—Middle of the posterior shaft of the radius, and adjacent membrane.
Insertion.—Base of the first phalanx of the thumb, on dorsal aspect.
Nerve Supply.—Posterior interosseous branch of the musculospiral.
Action.—Extends the first phalanx of the thumb.

Extensor Longus Pollicis.—(O. T. Extensor secundi internodii pollicis.) (Fig. 137.)
Location.—Deep in the lower part of the back of the forearm.
Origin.—Middle of the posterior shaft of the ulna and adjacent membrane.
Insertion.—The base of the second phalanx of the thumb, dorsal aspect.

Nerve Supply.—Posterior interosseous branch of the musculo-spiral.

Action.—Extends the second phalanx of the thumb.

Abductor Pollicis. (Fig. 140.)

Location.—Superficial on the ball of the thumb.

Origin.—Trapezium, scaphoid, and annular ligament, palmar aspect.

Insertion.—Base of the first phalanx of the thumb, on the radial side.

Nerve Supply.—Median.

Action.—Abducts the thumb, *i. e.*, draws it forward in a plane at right angles with the palm.

Adductor Pollicis. (Fig. 143.)

Location.—Deep in the radial side of the palm.

Origin.—Os magnum, bases of second and third metacarpal bones, and annular ligament. Lower two-thirds of the third metacarpal shaft, palmar aspect.

Insertion.—Inner side of the base of the first phalanx of the thumb.

Nerve Supply.—Ulnar.

Action.—Adduction and flexion of first phalanx of thumb, carrying toward the palm of the hand.

Palmaris Brevis.—A small muscle on the ulnar side of the hand, under the skin. It originates on the palmar fascia and the anterior annular ligament. It is inserted into the skin on the ulnar border of the hand. Its action is to corrugate the skin.

In the anatomical position, all the flexor muscles of the upper extremity raise the parts on which they act against gravity, which thus serves as an antagonist both in returning the parts to their former position and releasing the extensor groups from the work of opposition. To develop their power, the extensors require more resistance than the flexors provide in this situation.

In the lower extremity, the extensors of the hip and knee, with the extensors of the ankle, work against gravity, as an opposing force. The flexors of the hip and knee, with those also of the ankle, are assisted by gravity. Note the greater strength of the calf muscles as compared with those which flex the ankle.

THE MUSCLES OF THE LOWER EXTREMITY.

Movements of the Thigh.—As the hip-joint is a ball-and-socket joint, all kinds of movement are possible here, as in the shoulder-joint, though there is less freedom. Forward movement of the thigh is *flexion;* backward movement is *extension;* sideways outward is *abduction;* sideways inward is *adduction; circumduction* is the combination of these and *rotation* takes place as in the arm.

Movements of the Leg.—At the knee-joint, *flexion* is movement backward; *extension* is forward; and the small amount of rotation

at the end of extension and beginning of flexion is respectively outward and inward.

Movements of the Foot.—At the hinge of the ankle, movement upward is *flexion*, sometimes called *dorsi-flexion;* movement downward is *extension.* The movement of *inversion,* turning the sole toward the middle line, and its reverse of *eversion,* take place at the medio-tarsal and astragalo-calcaneal joints.

Movements of the Toes.—*Flexion* of the toes is movement downward; *extension* is movement upward, while *adduction* and *abduction* take place at the metatarso-phalangeal joints, toward and from the middle line of the second toe.

THE MUSCLES MOVING THE THIGH.

(See Figs. 184 to 191, pages 226 to 229.)

Flexors.	*Extensor.*
Psoas magnus	Gluteus maximus
Iliacus	
Abductors.	*Adductors.*
Tensor fasciæ latæ	Adductor magnus
Gluteus medius	Adductor longus
Gluteus minimus	Adductor brevis
	Adductor gracilis
	Pectineus
Internal rotators.	*Outward rotators.*
Tensor fasciæ latæ	Obturator externus
Gluteus medius	Obturator internus
Gluteus minimus	Pyriformis
	Gemellus superior
	Gemellus inferior
	Quadratus femoris

Psoas Magnus or Major.—(Fig. 144.)

Location.—Back part of the abdomen and upper part of thigh.

Origin.—Bodies of the last thoracic, and all the lumbar vertebræ, the cartilages between, with the transverse processes.

Insertion.—The lesser trochanter of the femur.

Nerve Supply.—Second and third lumbar.

Action.—With the pelvis fixed, flexes the thigh upon the trunk. With the femur fixed, flexes the lumbar spine. With one side acting, draws the lumbar spine to the same side. In unison with the iliacus, it tilts the pelvis forward. Helps to maintain erect position by supporting the trunk on the thighs.

Iliacus. (Fig. 144.)

Location.—In the hind wall of the abdomen and upper part of the thigh.

Origin.—The iliac fossa, and the ala of the sacrum.

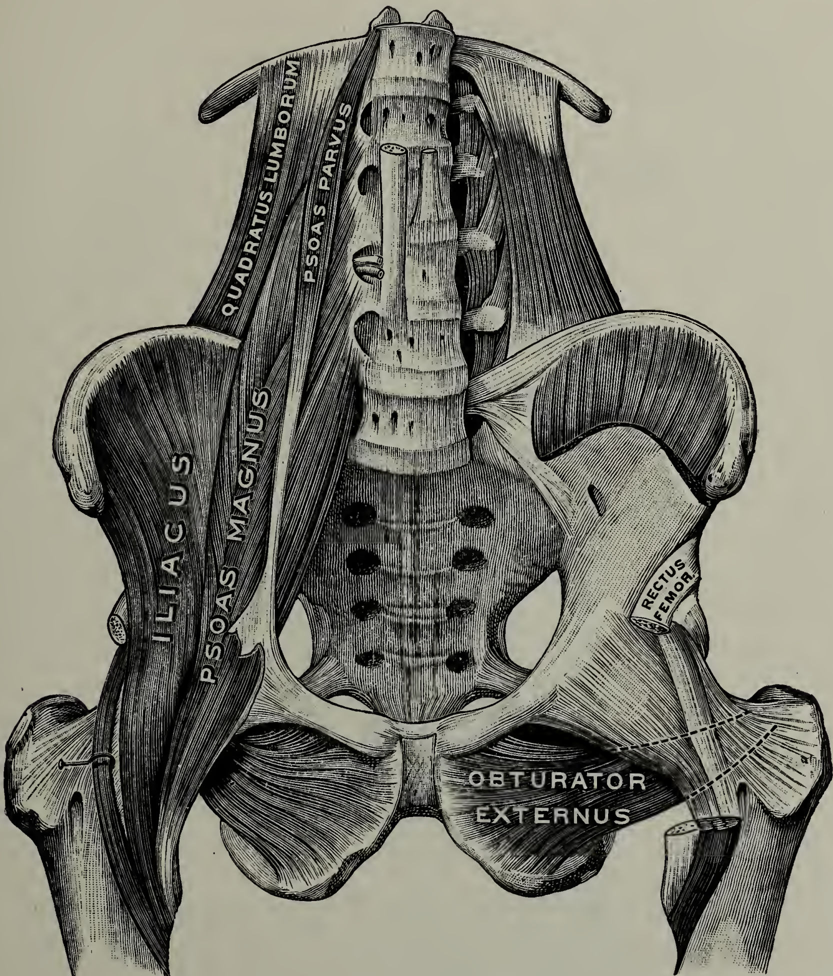


Fig. 144.—Psoas, iliacus and obturator externus muscles. (Testut.)

Insertion.—The lesser trochanter, along with the psoas magnus.

Nerve Supply.—Anterior crural.

Action.—With the psoas, it flexes and rotates the thigh inward. These two muscles are often referred to as one, the iliopsoas.

Gluteus Maximus. (Fig. 145.)

Location.—Forming most of the buttock.

Origin.—Outer lip of the iliac crest (posterior fourth).

Dorsal surface of the ilium between the crest and superior gluteal line; two lower segments of the sacrum and the coccyx.

The aponeurosis of the erector spinæ.

Insertion.—Gluteal ridge of femur and fascia lata.

Nerve Supply.—Inferior gluteal.

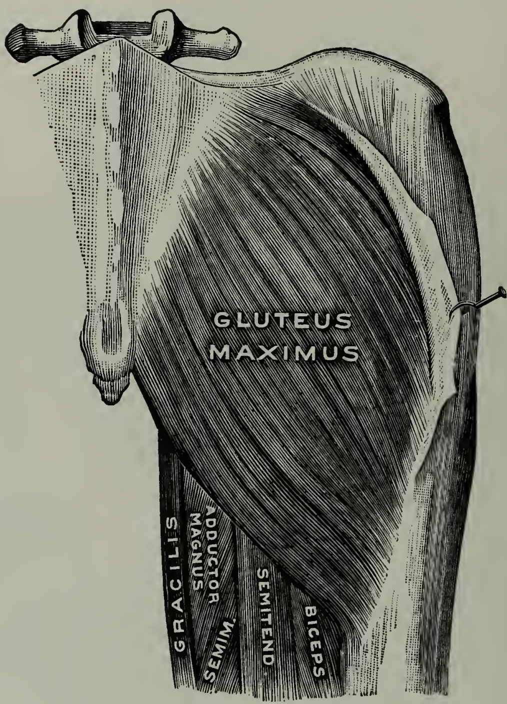


Fig. 145.—Gluteus maximus of right side. (Testut.)

Action.—Extension of the thigh and outward rotation. With the femur the fixed point, it supports the trunk in the erect position. Helps to raise the trunk from a flexed position. Tenses the fascia lata, thus helping to steady the femur on the tibia.

Tensor Fasciæ Latæ.—(O. T. Tensor vaginæ femoris.) (Fig. 146.)

Location.—Upper and outer aspect of the thigh, anteriorly.

Origin.—Just below the crest of the ilium, back of the anterior-superior spine.

Insertion.—Into the fascia lata, below the great trochanter.[1]

[1] See page 235 for *fascia lata*.

Nerve Supply.—Superior gluteal.

Action.—Abduction and inward rotation of the thigh; tensing the fascia lata. Helps to steady the trunk on the thigh, and the thigh on the leg.

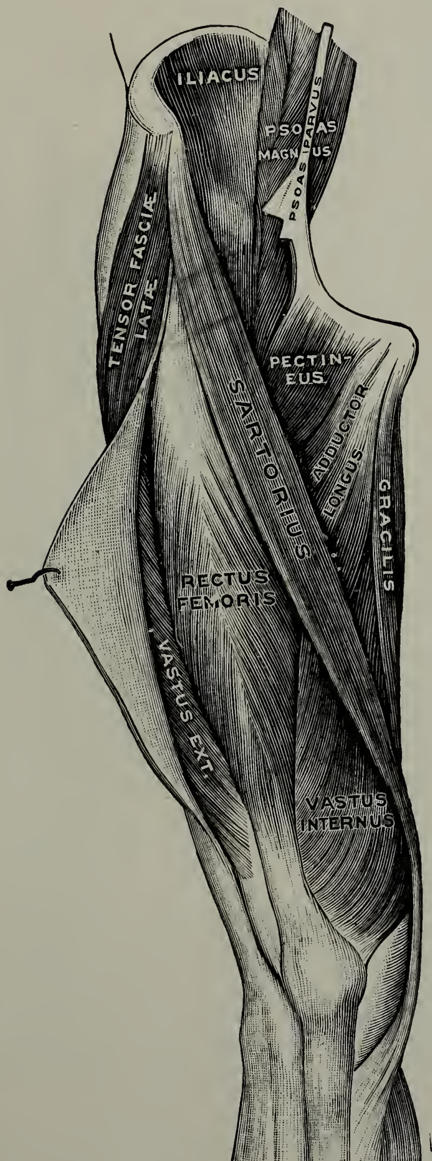


Fig. 146.—Superficial muscles in front part of the right thigh. (Testut.)

Gluteus Medius. (Fig. 147.)

Location.—Outer part of the hip, forming part of the buttock.

Origin.—The space between the superior and middle gluteal ridges of the ilium.

Insertion.—Outer surface of the great trochanter.

Nerve Supply.—Superior gluteal.

Action.—Abduction of the thigh when it is extended, and inward rotation of the thigh when it is flexed.

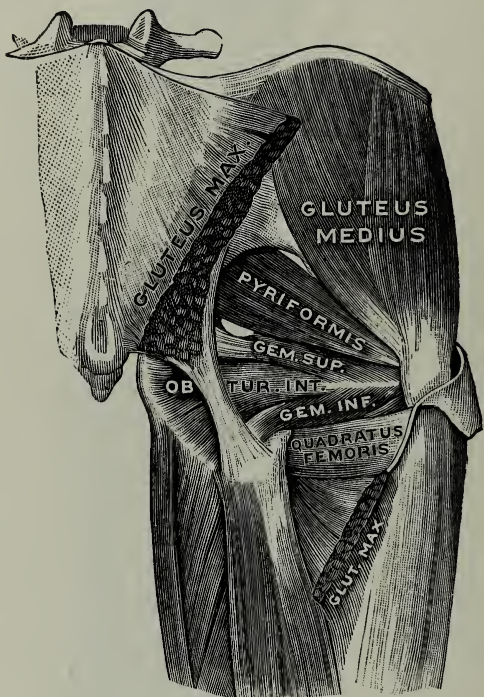


Fig. 147.—Muscles of right hip, viewed from behind, the gluteus maximus having been cut away. (Testut.)

Gluteus Minimus. (Fig. 149.)

Location.—The outer part of the hip, under the medius.

Origin.—Between the middle and inferior gluteal ridges, on the dorsum of the ilium.

Insertion.—The front of the great trochanter.

Nerve Supply.—Superior gluteal.

Action.—Abduction of the extended, inward rotation of the flexed thigh.

Adductor Magnus. (Figs. 148, 149.)

Location.—The full length of the inner side of the thigh.

Origin.—Rami of pubis and ischium, and the ischial tuberosity.

Insertion.—Gluteal ridge, inner lip of linea aspera, internal condylar ridge and adductor tubercle of femur.
Nerve Supply.—Obturator and great sciatic.

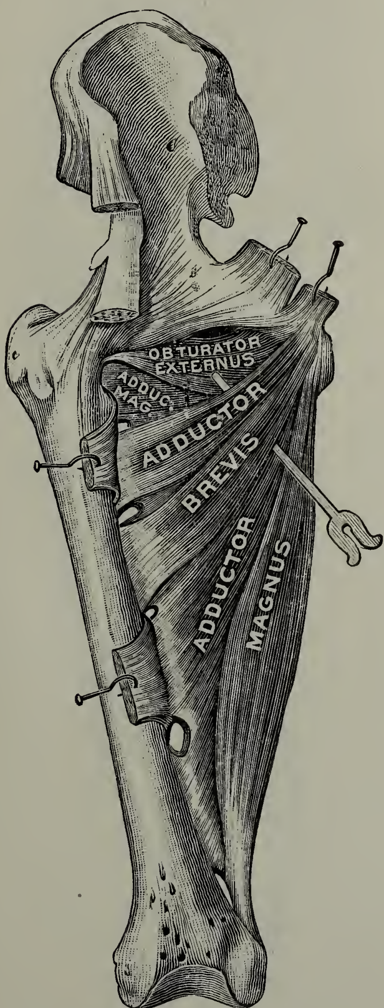


Fig. 148.—Adductores magnus and brevis of right side. (Testut.)

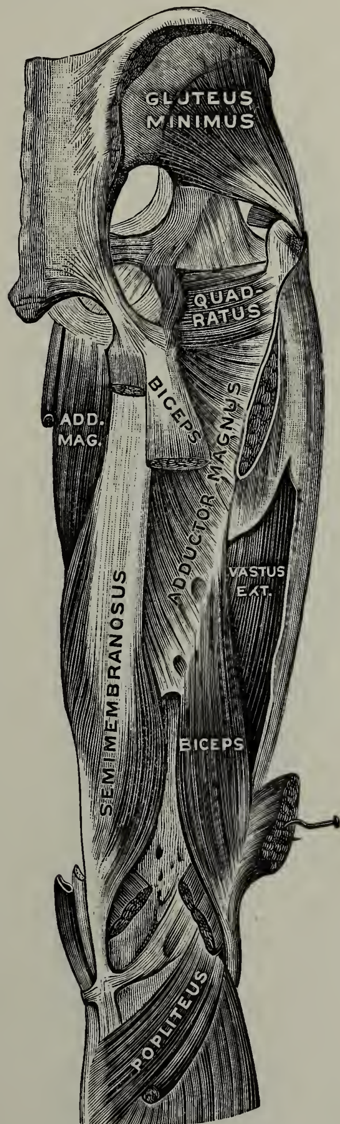


Fig. 149.—Muscles in deep portion of dorsum of right thigh, the semitendinosus and most of the biceps having been removed. (Testut.)

Action.—Adduction of thigh and outward rotation. The fibers coming from the ischial tuberosity extend the thigh upon the pelvis.

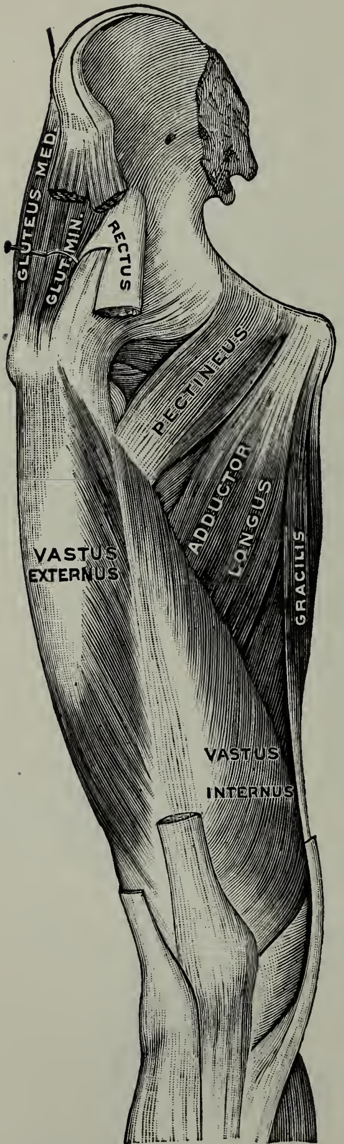


Fig. 150.—Muscles in the right thigh, viewed from in front, after removal of the rectus and sartorius. (Testut.)

Fig. 151.—Muscles in the dorsum of the right thigh. (Testut.)

Adductor Longus. (Fig. 150.)

Location.—Inner side of the thigh.

Origin.—Body of the pubic bone near the angle.

Insertion.—The middle third of the linea aspera, inner lip.

Nerve Supply.—Obturator.

Action.—Adducts, flexes and outwardly rotates the thigh.

Adductor Brevis. (Fig. 148.)

Location.—Inner and upper side of the thigh.

Origin.—Body and descending ramus of the os pubis.

Insertion.—Upper part of the linea aspera.

Nerve Supply.—Obturator.

Action.—Adducts, flexes and outwardly rotates the thigh.

Adductor Gracilis. (Fig. 150.)

Location.—Inner side of the thigh and back of knee.

Origin.—Descending ramus and symphysis of the os pubis.

Insertion.—Upper part of the inner aspect of the tibia, near the tubercle, in association with the tendons of the sartorius and semitendinosis.

Nerve Supply.—Obturator.

Action.—Flexes the leg, and inwardly rotates it.

Pectineus. (Fig. 150.)

Location.—Between the front of the pelvis and the back of the thigh.

Origin.—Iliopectineal line of ilium, and surface in front of it.

Insertion.—Upper half of the pectineal line behind the small trochanter.

Nerve Supply.—Anterior crural, and sometimes the obturator.

Action.—Adducts, flexes and slightly rotates the thigh outwardly.

Obturator Externus. (Fig. 148.)

Location.—Outer surface of the pelvis.

Origin.—The outer surface of the obturator membrane, the contiguous bony surface, and the rami of the os pubis and ischium.

Insertion.—Bottom of the digital fossa.

Nerve Supply.—Obturator.

Action.—Adducts and rotates thigh outwardly.

Obturator Internus. (Fig. 151.)

Location.—On the inner wall of the pelvis.

Origin.—Inner surface of the obturator membrane; margin of foramen; and space between the foramen, iliopectineal line and great sacro-sciatic foramen.

Insertion.—Inner surface of great trochanter, toward the front.

Nerve Supply.—Branch from the sacral plexus.

Action.—Outward rotation, when thigh extended; abducts the thigh when flexed.

Pyriformis. (Fig. 147.)

Location.—On the posterior wall of the true pelvis.

Origin.—Posterior border of ilium below the inferior spine; ventral surface of the second, third and fourth segments of the sacrum.

Insertion.—Upper border of great trochanter, anteriorly.

Nerve Supply.—Branch from the sacral plexus.

Action.—Outward rotation when thigh is extended; abducts when flexed.

Gemellus Superior and Inferior. (Fig. 147.)—Two small muscles, one above, the other below the obturator internus, and assisting in its work with similar insertion.

Quadratus Femoris. (Fig. 147.)

Location.—Back of the hip-joint.

Origin.—Outer border of the ischial tuberosity.

Insertion.—Quadrate line on back of femur.

Nerve Supply.—Branch from the sacral plexus.

Action.—Adducts and outwardly rotates thigh.

THE MUSCLES MOVING THE LEG.

Flexors.	*Extensors.*
*Sartorius	Quadriceps extensor cruris, comprising
*Biceps flexor cruris	**Rectus femoris
*Semitendinosus	Vastus lateralis
*Semimembranosus	Vastus medialis
Popliteus	Vastus intermedius

* These four flexors of the leg, cross the hip-joint as well. If flexion of the leg is prevented or is completed, they act to extend the thigh.

** This muscle passing over both the hip- and knee-joints, acts as a flexor of the thigh, when the leg is fully extended. If the thigh is fixed, it flexes the pelvis.

Sartorius. (Fig. 146.)

Location.—On the front of the thigh crossing over to the inner side of the knee.

Origin.—Anterior-superior spinous process of the ilium, and just below.

Insertion.—The upper part of the inner aspect of the tibia, near the tubercle.

Nerve Supply.—Anterior crural.

Action.—Flexes the leg and thigh with synchronous abduction of the thigh; then outward rotation.

Biceps Flexor Cruris. (Fig. 151.)

Location.—In the back of the thigh and knee-joint.

Origin.—Long head, the tuberosity of the ischium.

Short head, the lower part of the linea aspera and upper two-thirds of the external condylar ridge.

Insertion.—The head of the fibula.

Nerve Supply.—Great sciatic.

Action.—Flexes the leg, with external rotation. Extends the thigh.

Semitendinosus. (Fig. 151.)

Location.—Inner side of the back of the thigh.

Origin.—Tuberosity of the ischium.

Insertion.—Upper part of the inner aspect of the tibia, near the tubercle.

Nerve Supply.—Great sciatic.

Action.—Flexes the leg, then rotates it inward. Extends the thigh.

Semimembranosus. (Figs. 149, 151.)

Location.—Inner side of the back of the thigh.

Origin.—Tuberosity of the ischium.

Insertion.—A groove on the inner and posterior aspect of the inner tuberosity of the tibia.

Nerve Supply.—Great sciatic.

Action.—Flexes leg, than rotates it inward. Extension of the thigh.

Note.—The tendons of the gracilis, sartorius, semitendinosus, and semimembranosus form the "inner hamstrings." The tendon of the biceps flexor cruris forms the "outer hamstring." This group of muscles, by passing over the hip-joint, serve to maintain the trunk erect upon the thighs. They limit flexion of the thighs upon the pelvis, unless they first flex the knees.

Popliteus. (Fig. 149.)

Location.—Back of the knee, close to the joint.

Origin.—The outer side of the external condyle of the femur.

Insertion.—Above the oblique line of the tibia, on a triangular area.

Nerve Supply.—Internal popliteal branch of the great sciatic.

Action.—Flexes and rotates leg inward.

The Quadriceps Femoris (Quadriceps extensor cruris) is a compound of four muscles, placed on the thigh and enveloping it, front and sides, leaving only part of the linea aspera uncovered. The insertion of the combination is through one large tendon, to the tubercle of the tibia. In this tendon the sesamoid bone, the patella, is developed.

Rectus Femoris. (Fig. 146.)

Origin.—Anterior-inferior spine of the ilium with a reflected tendon from above the acetabulum.

Insertion.—The tubercle of the tibia.

Nerve Supply.—Anterior crural.

Action.—Extends the leg and flexes the thigh. It helps to steady the trunk upon the thigh.

Vastus Lateralis.—(O. T. Vastus externus.) (Figs. 150 and 152.)

Location.—On the outer and back part of the thigh.

Origin.—Anterior intertrochanteric line; base of great trochanter; the gluteal ridge, and the outer lip of the linea aspera.

Insertion.—The tubercle of the tibia.

Nerve Supply.—Anterior crural.

Action.—Extends the leg.

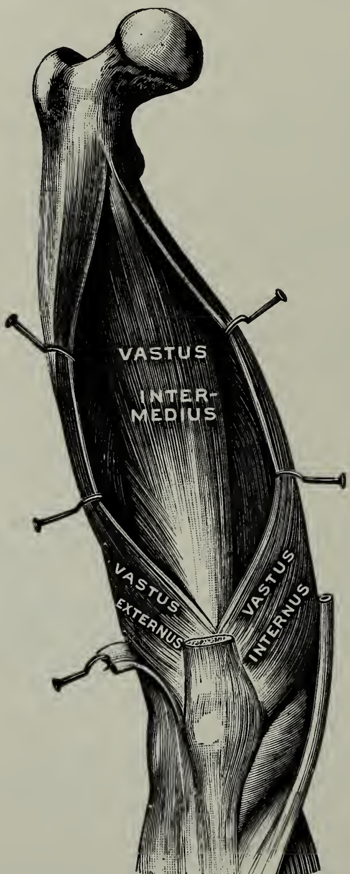


Fig. 152.—Vastus intermedius of right side. (Testut.)

Vastus Medialis.—(O. T. Vastus internus.) (Figs. 150, 152.)

Location.—On the inner part of the thigh.

Origin.—Spiral line, inner lip of linea aspera, and internal supracondylar ridge.

Insertion.—The tubercle of the tibia.

Nerve Supply.—Anterior crural.

Action.—Extends the leg.

Vastus Intermedius.—(O. T. Crureus.) (Fig. 152.)

Location.—Deep on the front of the thigh.

Origin.—The upper two-thirds of the shaft of the femur, anteriorly.

Insertion.—The tubercle of the tibia.

Nerve Supply.—Anterior crural.

Action.—Extends the leg.

A few muscular fibers arise from the lower part of the femur, and are inserted into the synovial membrane of the knee-joint. This is the *musculus articularis genu,* or muscle of the knee-joint. Its function is to pull the synovial membrane out of the way of being pinched in extension of the knee.

THE MUSCLES MOVING THE FOOT.

(See Figs. 190, 191)

Flexors.	*Extensors.*
Tibialis anterior	Tibialis posterior on inner side
Peroneus tertius	Gastrocnemius, Soleus, Plantaris } in the center
	Peroneus longus, Peroneus brevis } on outer side

Tibialis Anterior.—(O. T. Tibialis anticus.) (Fig. 153.)

Location.—On the front and outer side of the leg.

Origin.—Outer tuberosity and upper two-thirds of the external surface of the tibia and adjacent interosseous membrane.

Insertion.—Inner surface of the internal cuneiform bone, and the base of the first metatarsal.

Nerve Supply.—Anterior tibial branch of the great sciatic.

Action.—Flexes the foot upon the leg, raises the *inner* border and adducts the front of the foot. Or flexes and inverts foot.

Peroneus Tertius. (Fig. 153.)

Location.—Lower front part of the leg.

Origin.—Lower fourth of the anterior surface of the fibula and adjacent membrane.

Insertion.—Base of the fifth metatarsal, upper surface.

Nerve Supply.—Anterior tibial branch of the great sciatic.

Action.—Flexes foot, raises *outer* border and abducts front, or eversion of the foot.

Tibialis Posterior.—(O. T. Tibialis posticus.) (Fig. 154.)

Location.—Deep in the back of the leg, and crossing the sole of the foot.

Origin.—The lateral half of the middle third of the posterior surface of the tibia. Upper two-thirds of the shaft of the fibula, and the adjacent interosseous membrane.

Insertion.—Tuberosity of the scaphoid, with off-shoots to the three cuneiform, the cuboid, the bases of the second, third and fourth metatarsals, and to the sustentaculum tali of the calcaneum. (Thereby getting a grip on the entire sole, after passing back of the inner malleolus. Very important in maintaining the arch of the foot.)

Nerve Supply.—Posterior tibial branch of the great sciatic.

Action.—Extends the foot on the leg; raises the *inner* border and adducts the front of the foot. Or extends and inverts foot.

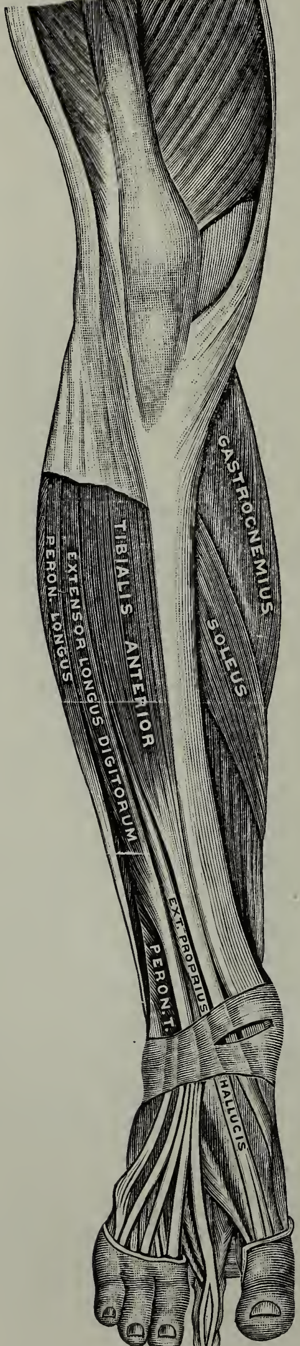


Fig. 153.—Muscles in the right leg, viewed from in front. (Testut.)

Fig. 154.—Muscles in the deep layer of the dorsum of the right leg. (Testut.)

FIG. 155.—Gastrocnemius of right side. (Testut.)

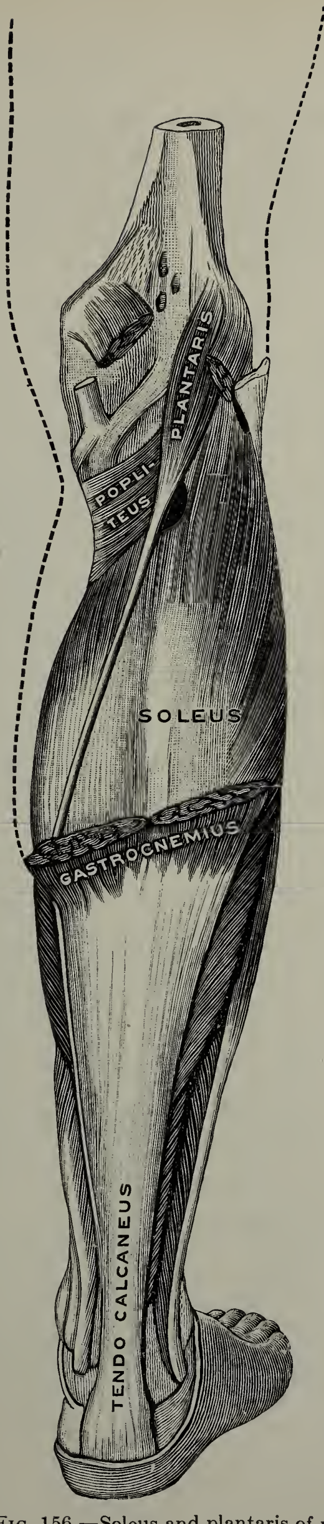


FIG. 156.—Soleus and plantaris of right side. (Testut.)

Gastrocnemius. (Fig. 155.)

Location.—Superficial in the calf of the leg.

Origin.—By two heads, from the inner and outer condyles of the femur, and just above.

Insertion.—By the tendo Achillis, to the back of the calcaneum.

Nerve Supply.—Internal popliteal branch of the great sciatic.

Action.—Extends the foot upon the leg. Flexes the leg on the thigh. With the soleus, raises the weight of the body.

Soleus. (Fig. 156.)

Location.—Deep in the calf of the leg.

Origin.—Head and upper third of the posterior surface of the fibula. Oblique line and inner border of tibia to the middle of the shaft.

Insertion.—The back of the calcaneum, by the tendo Achillis.

Nerve Supply.—Internal popliteal and posterior tibial branches of the great sciatic.

Action.—Extends foot on leg. When upright, the weight of the body is raised by extension of foot.

Plantaris.—A small muscle, arising from above the external condyle of the femur, and inserted with the above two. Slight action in extending foot and flexing leg. (Fig. 156.)

Peroneus Longus. (Figs. 154 and 157.)

Location.—On the outer side of the leg.

Origin.—Head and upper two-thirds of outer surface of the fibula; the outer tuberosity of the tibia.

Insertion.—Passing back of the outer malleolus, the tendon of insertion, goes forward on the outer side of the calcaneum, and through the groove in the cuboid, diagonally forward and inward across the sole to the under surface of the inner cuneiform and the base of the first metatarsal bone.

Nerve Supply.—Branch of the external popliteal division of the great sciatic.

Action.—Extends the foot, raises the *outer* side and abducts the front. Or extension and eversion, with depression of the great toe.

Peroneus Brevis. (Fig. 157.)

Location.—Lower and outer part of the leg.

Origin.—The lower two-thirds of the outer surface of the fibula.

Insertion.—Outer side of the fifth metatarsal, on its tuberosity.

Nerve Supply.—Branch of the external popliteal division of the great sciatic.

Action.—Extends foot, raises the *outer* side and abducts the front. Or eversion.

Note the combined action of the tibialis anterior and posterior in inverting the foot, with their antagonistic action at the ankle-joint; also, that the peroneal muscles combine in everting the foot, though

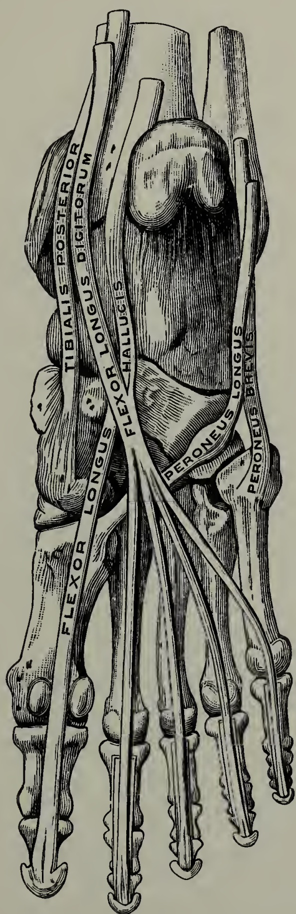


Fig. 157.—Tendons in the right sole. (Testut.)

the tertius opposes the other two in its action at the ankle-joint. As a group the tibial muscles oppose the peroneals at the medio-tarsal joint. With the foot fixed, these muscles help to hold the leg erect upon the ankle. Their balanced action prevents mal-positions of the foot, such as flatfoot and clubfoot.

THE MUSCLES MOVING THE TOES.

Flexors.	*Extensors.*
*Flexor longus hallucis	*Extensor proprius hallucis
Flexor brevis hallucis	*Extensor longus digitorum
*Flexor longus digitorum	Extensor brevis digitorum
Flexor accessorius	
Flexor brevis digitorum	
Flexor brevis minimi digiti	
Lumbricales	

* These muscles act on the toes but are in the leg.

Abductors.	*Adductors.*
Abductor hallucis	Adductor obliquus hallucis
Abductor minimi digiti	Adductor transversus hallucis
Interossei dorsales	Interossei plantares

Flexor Longus Hallucis. (Figs. 154, 157.)

Location.—Deep in the back of the leg and in the sole of the foot.

Origin.—Lower two-thirds of the posterior surface of the fibula, and adjacent interosseous membrane.

Insertion.—Under surface of the base of the second phalanx of the great toe. Tendon passes back of the inner malleolus, and beneath the sustentaculum tali.

Nerve Supply.—Posterior tibial branch of the great sciatic.

Action.—Flexes last phalanx of the great toe. Extends foot at the ankle.

Flexor Brevis Hallucis. (Figs. 158, 159.)—Originates from the cuboid and the tendon of the tibialis posterior, passing by two tendons to the two sides of the base of the first phalanx of the great toe, in common with the abductor and adductor of same. Each tendon encloses a sesamoid bone, and in the middle is the tendon of the long flexor of the great toe. The action is to flex the great toe.

Flexor Longus Digitorum. (Figs. 154, 157.)

Location.—Deep in the back of the leg, and in the sole of the foot.

Origin.—Inner part of the posterior surface of the tibia, the middle two-fourths.

Insertion.—By four tendons to the base of the third phalanx of the four lesser toes. The tendon of the muscle passes behind the inner malleolus, forward in the sole, and divides into four slips just above the heads of the metatarsal bones. It goes through the perforated slips of the brevis to be attached to the last phalanx.

Nerve Supply.—Posterior tibial branch of the great sciatic.

Action.—Flexes the last phalanx of the four lesser toes. Extends the foot.

Flexor Accessorius. (Fig. 195.)—A muscle originating on the calcaneum, passing forward in the sole to the outer posterior border

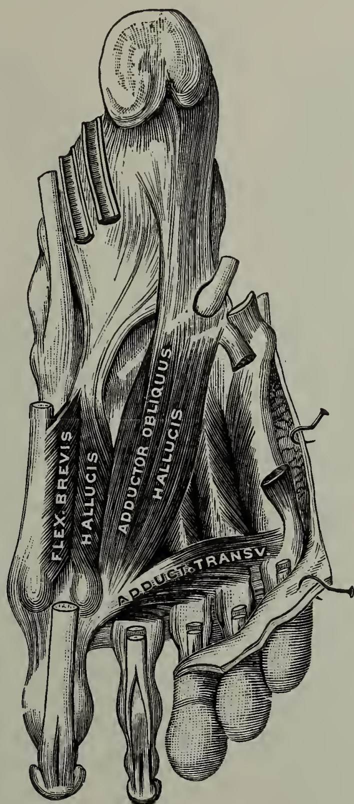


Fig. 158.—Muscles in the third layer of the right sole. The belly of the flexor brevis minimi digiti has been removed. (Testut.)

and upper surface of the tendon of the flexor longus digitorum. It flexes the small toes, and brings into line with the long axis of the foot, the line of action of the longus digitorum.

Flexor Brevis Digitorum. (Fig. 160.)

Location.—Sole of the foot.

Origin.—Front of the calcaneum.

Insertion.—By four tendons to the sides of the second phalanx of the four lesser toes.

Nerve Supply.—Internal plantar branch of the great sciatic.

Action.—Flexes second phalanx of the four lesser toes.

Flexor Brevis Minimi Digiti Pedis. (Fig. 159.)—A small muscle which flexes the first phalanx of the smallest toe.

Lumbricales. (Fig. 159.)—Like the lumbricales of the hand, these muscles pass between the flexor and extensor tendons of the toes. They flex the first phalanx and extend the second and third phalanges of the four lesser toes.

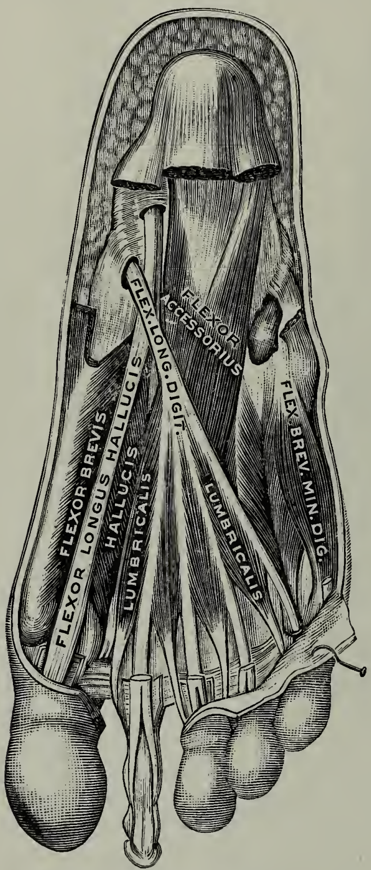


Fig. 159.—Flexor accessorius and lumbricales of right foot. (Testut.)

Fig. 160.—Muscles of the superficial layer of the right foot. (Testut.)

Extensor Proprius Hallucis. (Fig. 153.)

Location.—In the front of the leg and the dorsum of the foot.

Origin.—Middle two-fourths of the fibula, anteriorly, and adjacent interosseous membrane.

Insertion.—Base of the last phalanx of the great toe, on dorsum.

Nerve Supply.—Anterior tibial branch of the great sciatic.

Action.—Extends the great toe. Flexes the foot on the leg.

Extensor Longus Digitorum. (Fig. 153.)

Location.—In the front of the leg and dorsum of the foot.

Origin.—Outer tuberosity of the tibia; head and upper two-thirds of the fibula, anteriorly; and the adjacent interosseous membrane.

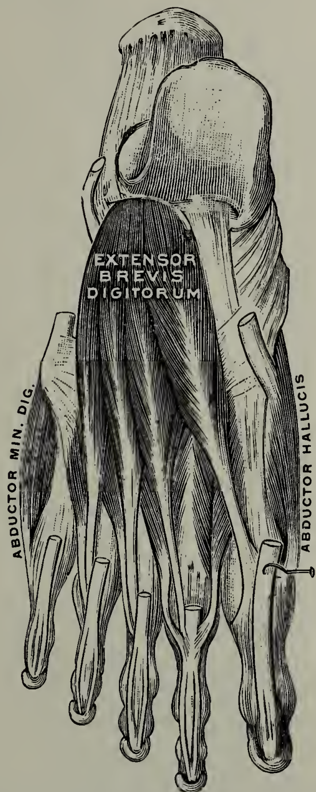


Fig. 161.—Extensor brevis digitorum of right foot. (Testut.)

Insertion.—The tendon divides into four slips, which are inserted into both the second and third phalanges of the four lesser toes.

Nerve Supply.—Anterior tibial branch of the great sciatic.

Action.—Extends the four lesser toes. Flexes the foot at the ankle.

Extensor Brevis Digitorum.—A small muscle, entirely in the dorsum of the foot, which is inserted by four tendons into the first phalanx of the great toe, and to the extensor tendon of the longus for the next three toes. Helps to extend the toes. (Fig. 161.)

Abductor Hallucis. (Fig. 160.)—Passing from the calcaneum forward, this is inserted into the inner side of the base of the first

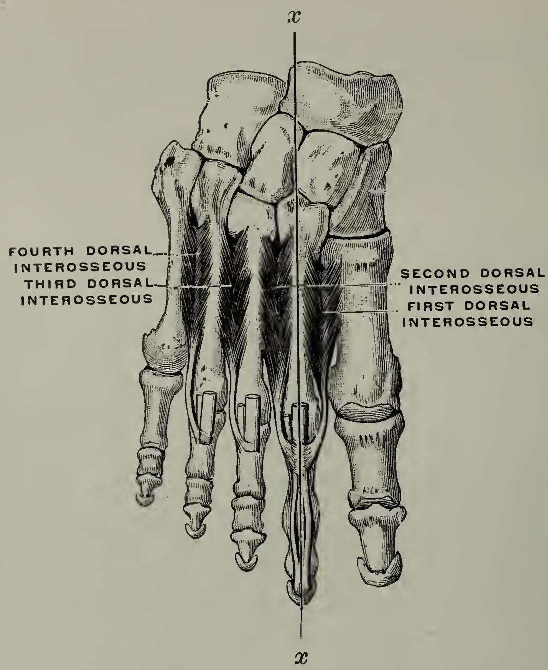


Fig. 162.—Interossei dorsales of right foot. The line *x x* is that from which abduction is made. (Testut.)

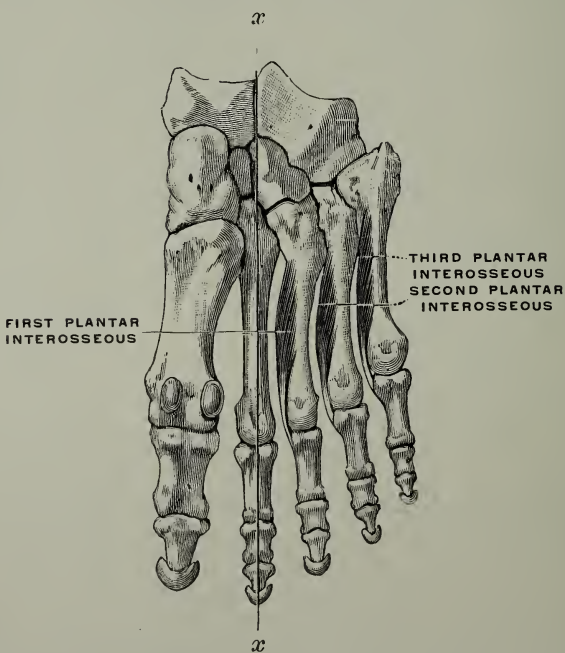


Fig. 163.—Interossei plantares of right foot. The line *x x* is that to which adduction is made. (Testut.)

phalanx of the great toe, with the inner head of the flexor brevis hallucis. It flexes and abducts the great toe.

Abductor Minimi Digiti Pedis. (Figs. 160, 161.)—Passing from the calcaneum forward, this is inserted into the outer side of the little toe, first phalanx. It abducts the little toe.

Interossei Dorsales Pedis. (Fig. 162.)

Interossei Plantares. (Fig. 163.)—The interossei muscles of the foot serve as adductors and abductors of the toes, to and from the line passing through the second toe, in the same way as in the hand.

Two special adductors of the great toe, the oblique and transverse adductors, pass between the great toe and the little toe, helping to preserve the transverse arch of the foot. (Fig. 158.)

THE MUSCLES OF THE TRUNK.

The muscles of the trunk may be divided into three groups:

Those of the back, including some of the neck muscles.

Those of the abdomen.

Those of the thorax.

The Muscles of the Back.—The muscles of the back comprise five layers, none of which are entirely complete. In the first layer are the *trapezius* and the *latissimus dorsi*. In the second layer are the *levator scapulæ* and the *rhomboidii major* and *minor*.

The Muscles in the Third Layer of the Back.

Serratus posterior, superior, and inferior.

Splenius capitis, and cervicis.

Serratus Posterior Superior.—(O. T. Serratus posticus superior.) (Fig. 164.)

Location.—Upper part of the thorax.

Origin.—Lower part of the ligamentum nuchæ; spinous processes of the last cervical and two or three upper dorsal.

Insertion.—Second to the fifth ribs, beyond the angles.

Nerve Supply.—Second and third intercostals.

Action.—Raises the upper ribs. In reversed action, helps to extend the spine. Probably acts in forced inspiration.

Serratus Posterior Inferior.—(O. T. Serratus posticus inferior.) (Fig. 126.)

Location.—Lower part of the back of the thorax.

Origin.—Spinous processes of the two lower dorsal and two upper lumbar vertebræ.

Insertion.—A little beyond the angles of the four lower ribs, on their inferior borders.

Nerve Supply.—Tenth and eleventh intercostal.

Action.—Draws down and backward the lower ribs, probably in forced inspiration. Helps to fix the lower ribs, assisting the diaphragm in inspiration. Resists the tendency of the diaphragm to raise the lower ribs.

Splenius Capitis.—(Fig. 164.)

Location.—The back of the neck, in front of the trapezius.

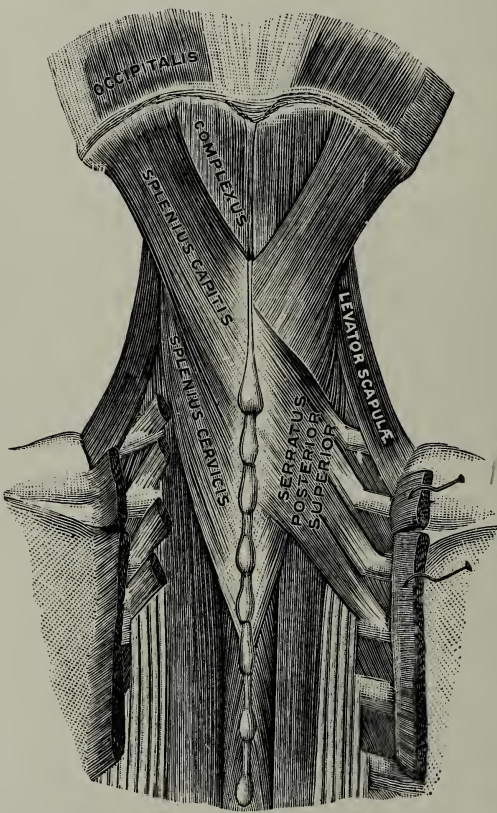


FIG. 164.—Muscles in the third layer of the back. (Testut.)

Origin.—From the lower half of the ligamentum nuchæ; the spine of the seventh cervical vertebra, and the spines of the upper three or four thoracic vertebræ.

Insertion.—Mastoid process of the temporal and adjacent part of the occipital bone.

Nerve Supply.—Second, third and fourth cervical nerves.

Action.—Inclines and rotates the head and neck toward the side on which muscle is placed. When both sides act, the head and neck are extended.

Splenius Cervicis.—(O. T. Splenius colli.) (Fig. 164.)

Location.—Lower part of the back of the neck.

Origin.—Spinous processes of the third to sixth thoracic vertebræ.

Insertion.—Posterior tubercles of the first two or three cervical vertebræ.

Nerve Supply.—Second, third and fourth cervical.

Action.—Inclines and rotates the neck toward the side on which the muscle lies. When both act, the neck is extended.

The Muscles in the Fourth Layer of the Back. (Figs. 165, 166, 167.)

The Sacro-spinalis or Erector Spinæ.—The muscles in this layer comprise what is known as the *erector spinæ* group, extending from the lower end of the spine to the head. They occupy the grooves on each side of the spinal column. The muscles originate as a tendinous sheet, covering the sacral region, with the muscle mass filling the space between the iliac crest and the lowest ribs. This is covered by the lumbar fascia. This mass divides into three divisions, called the inner, outer, and middle divisions, which climb the back by relays.

The inner division is called the *spinalis dorsi.* (Fig. 165.) Its fibers start from the muscular mass near the middle of the thorax, and are inserted into the spines of the upper thoracic vertebræ, going by steps, three or four at a time.

The outer division goes from the twelfth rib to the lower part of the neck, while the middle division is carried all the way to the head. The outer division (Figs. 165, 167) begins as the *iliocostalis,* whose muscular slips start from the mass in the lumbar region, and climb up the ribs to the lower six or seven, near their angles. In close association with these, other slips pass upward from the six lower to the six upper ribs, as the *musculus accessorius ad iliocostalem,* or the accessory muscle of the iliocostalis. The slips have now been carried to the upper margin of the thorax, and a new series of slips relays the erector spinæ from the five ribs between the third and seventh, to the transverse processes of the cervical vertebræ between the fourth and sixth. This is the *cervicalis ascendens.*

The middle division, the longissimus dorsi (Figs. 165, 166, 167), sends slips up the back to the transverse processes of all the lumbar and thoracic vertebræ, and to the ribs between the angles and tubercles. These slips vary in length according to the distance gone. (In studying the illustrations, Figs. 166 and 167, notice that the muscle slips have been turned inside out by the hooks, so as to show the individual attachments. Fig. 165 shows the appearance of these muscles *in situ.*) The longissimus is prolonged upward by the

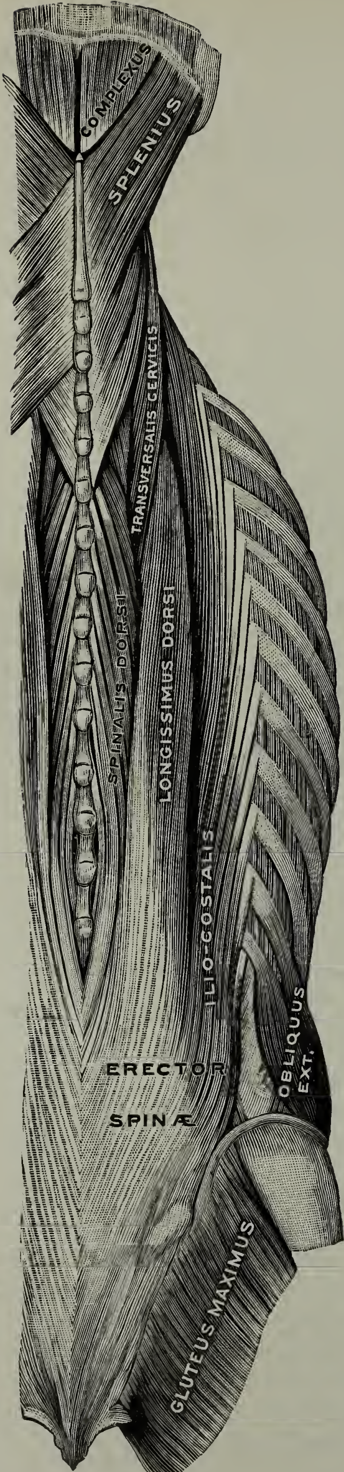


Fig. 165.—Erector spinæ, superficial view. (Testut).

Fig. 166.—Erector spinæ. The outer series is pulled outward. (Testut.)

transversalis cervicis or *colli.* Slips arise from the transverse processes of from four to six upper thoracic vertebræ and are inserted into the transverse processes of the cervical vertebræ from the second to the sixth. This division is further prolonged by the *trachelo-mastoideus,* which arising from the transverse processes of the upper four to six thoracic vertebræ, and the articular processes of the lower three or four cervical vertebræ, is carried through the neck to the mastoid process of the temporal bone.

The nerve supply of these small divisions comes from the contiguous spinal nerves.

While the erector spinæ as a whole is the length of the back, the subdivisions are neither large, nor long. As the belly of the muscles is the contracting part, there is a succession of short pulls on the different segments of the spine, making the movements gradual, sustained and powerful. The direct action of the group is the erection or extension of the trunk, with the fixed points at the lower part of the back. They hold the trunk, neck, and head erect, against the pull of gravity. The ileocostales, with the neck firm, elevate the ribs. If one side acts alone, lateral movement of the trunk to that side is produced. The contractual power of a muscle is measured by its physiological cross-section, so the sum of the cross-sections of these many muscles is equal to one very large one, such as would by its size show great power.

The Muscles in the Fifth Layer of the Back.

These lie in front of the fourth layer and consist of many small slips mostly arising from the transverse processes of the vertebræ, and going to the spinous processes of vertebræ four or five segments ahead.

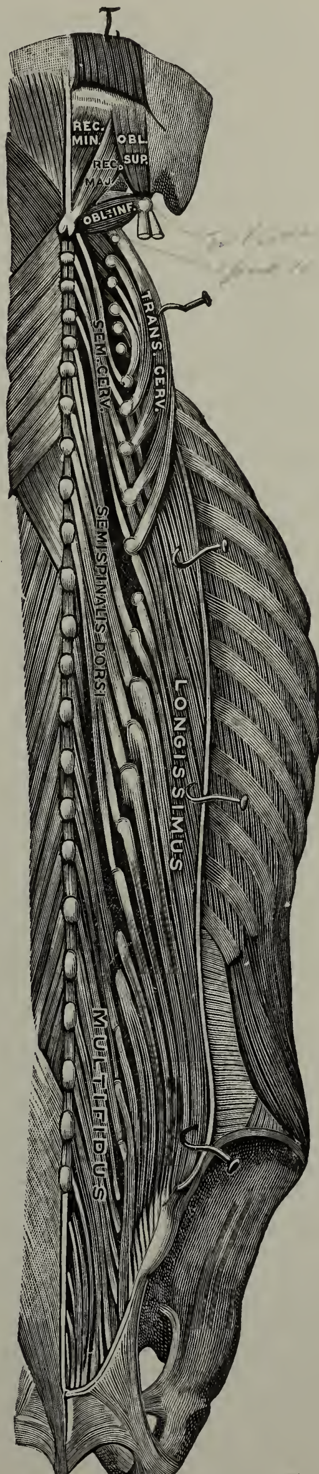


Fig. 167.—Erector spinæ. The middle series is pulled outward. (Testut.)

The names of these are:

Complexus, or *Semispinalis capitis*. (Figs. 166, 167.)
Semispinalis cervicis.
Semispinalis dorsi.
Multifidus spinæ.
Rotatores spinæ.

The *complexus* is the largest muscle of the group, and arises from the transverse processes of the upper six or seven thoracic vertebræ, the seventh cervical transverse process, and from the articular processes of the lower three or four cervical. It is inserted into the surface of the occiput between the superior and inferior curved lines.

Its action is to extend the head, but if only one side acts, it draws the head to the same side.

The *semispinalis cervicis* passes from the transverse processes of the upper five or six thoracic vertebræ to the spinous processes of the cervical vertebræ from the second to the fifth. It acts to extend the neck and spine, but if one side acts alone, the spine is flexed to that side with rotation.

The *semispinalis dorsi* originates from the transverse processes of the sixth to the tenth thoracic vertebræ, and the slips are inserted into the spinous processes of the upper four thoracic and the sixth and seventh cervical vertebræ. Its action is like that of the group above.

The *multifidus spinæ* consists of many small slips, which fill the hollow space on each side of the spinous processes from the sacrum to the axis. Their arrangement varies, some going to a spinous process three or four vertebræ above, some to a spine two steps above, while the deepest layer passes to the next spinous process above their origin. The fibers pass inward and upward. The lower fibers hold the spine firm, while the upper fibers extend it further up. As their arrangement is essentially the same as the others of this group, the action is the same as the above.

The *rotatores spinæ* act between the transverse processes of the thoracic vertebræ and the laminæ of the same. Their action is to rotate the spine to the *opposite* side, extend and flex laterally. The nerves supplying these muscles are from the spinal cord in the neighborhood.

A group of small muscles, the *suboccipital*, are more important than their size warrants, as they are seemingly often contracted without the consciousness of a person, producing considerable nervous strain. However, they are under the control of the will.

Suboccipital Muscles. (Fig. 167.)

Rectus capitis posterior major.
Rectus capitis posterior minor.
Obliquus capitis inferior.
Obliquus capitis superior.

These four muscles are deeply placed under the overhang of the occiput, and pass from the axis and atlas to the occiput. Their actions are to extend the head and rotate it, directly or by rotating the atlas carrying the head.

The suboccipital nerve supplies these muscles. Their involuntary, constant contraction interferes with the functioning of the sympathetic fibers in the region, thus exerting a widespread influence.

THE MUSCLES OF THE ABDOMEN.

Rectus abdominis	Obliquus internus abdominis
Pyramidalis	Transversus abdominis
Obliquus externus abdominis	Quadratus lumborum

These six muscles cover the abdominal cavity. They consist of sheets of muscle with fibrous aponeuroses. According to their development through exercise, these muscles are thick enough to be separated into layers, or they are so thin it is next to impossible to demonstrate them as distinct from each other.

Rectus Abdominis. (Fig. 168.)

Location.—In the front wall of the abdomen near the middle.

Origin.—The crest and symphysis of the os pubis.

Insertion.—The cartilages of the fifth, sixth and seventh ribs.

Nerve Supply.—Lower intercostal and iliohypogastric.

Action.—Flexes the spine, if one side is used; depresses the thorax; compresses the abdominal viscera; when thorax is fixed, it flexes the pelvis on the trunk. Tendinous inscriptions pass across the rectus, dividing it into four portions. These are more or less marked, according to the development of the muscle.

Pyramidalis.—An adjunct to the rectus, not always present. It passes from the pubic ramus to the lower part of the *linea alba.* It draws down the linea alba in the middle line. Same nerve supply as the *rectus.* Its shape gives it the name.

Obliquus Externus Abdominis. (Fig. 169.)

Location.—Superficial in the lateral wall of the abdomen.

Origin.—By eight fleshy digitations from the eight lower ribs beyond the cartilages. First five interdigitate with the serratus magnus, the lower three with the latissimus.

Insertion.—The anterior half of the outer lip of the crest of the ilium; Poupart's ligament; and the linea alba.

Nerve Supply.—Lower intercostals, ilioinguinal and iliohypogastric.

Action.—Compresses the abdominal viscera; depresses the thorax; flexes the spine; rotates the trunk to the opposite side, when only one side acts; with the thorax fixed, it flexes and rotates the pelvis to the same side.

Poupart's ligament is not a true ligament, but is the lower border of the obliquus externus abdominis between the anterior-superior spine of the ilium and the pubic tubercle. The muscle is covered by fascia, which folds under and forms a shelf-like structure, to which other muscles are attached. This is also called the *inguinal ligament.*

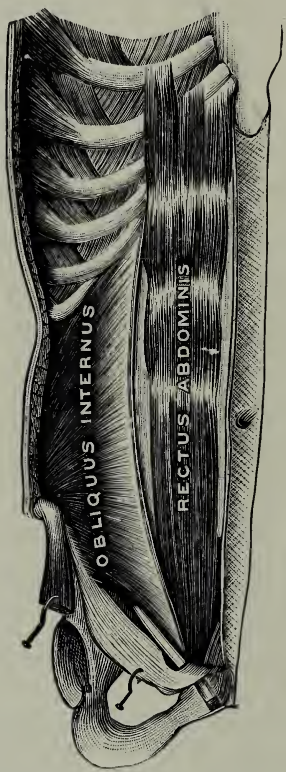


FIG. 168.—Rectus abdominis and obliquus internus of right side. (Testut.)

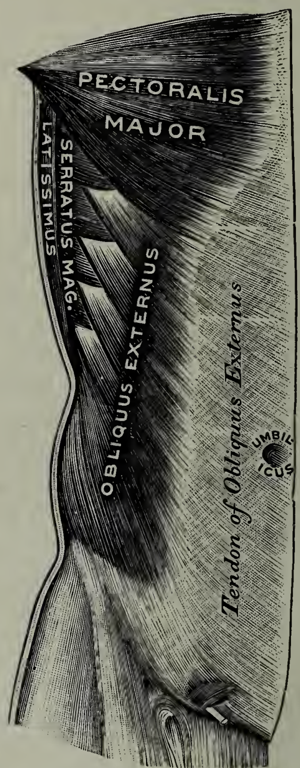


FIG. 169.—Obliquus externus abdominis of right side. (Testut.)

The tendon of insertion of the obliquus externus, internus, and the transversalis is a sheath of fibrous tissue that is in layers. On the front side that from the externus passes in front of the rectus, covering it. It is joined to the outer half of the internus aponeurosis, interlacing with the fibers from the other side of the abdomen to form a dense fibrous band, the "white line" or linea alba. The posterior half of the aponeurosis of the internus and that from the transversalis passes to the rear of the rectus, and forms the posterior part of its sheath. It then joins the other fibers to form the linea alba.

The Inguinal Canal.—The aponeurosis of the externus at the lower part, just above the body of the pubis, presents diverging fibers that form an opening, the external abdominal ring, the outer opening of the inguinal canal.

The inguinal canal is a passage way, about 4 cm. long, beginning in the *transversalis fascia,* as the internal abdominal ring (abdominal inguinal ring), running downward and inward to the external abdominal ring (subcutaneous inguinal ring). The internal abdominal ring is half way between the anterior-superior spinous process of the ilium and the symphysis pubis. In the male it contains the

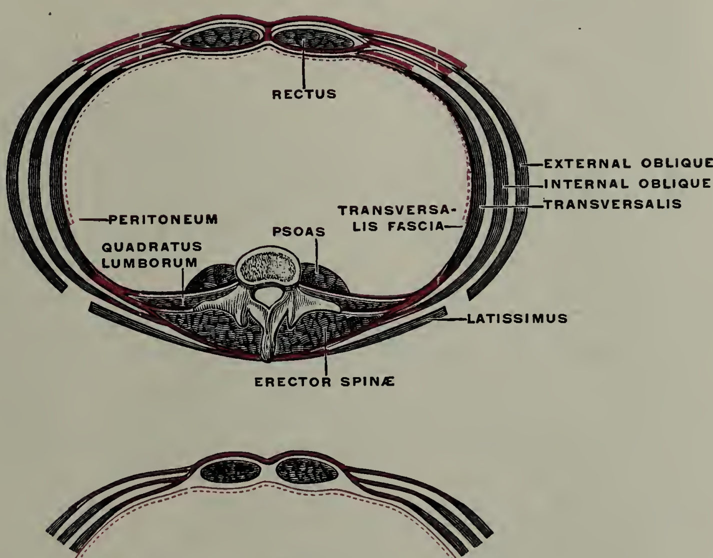


FIG. 170.—Semidiagrammatic horizontal section of trunk to show the lumbar fascia and the tendons of the lateral abdominal muscles. The upper figure shows the complete sheathing of the rectus in its superior portions; the lower shows the arrangement in its inferior fourth. (Testut.)

spermatic cord, some bloodvessels, and the ilio-inguinal nerve. In the female it transmits the round ligament of the uterus, some bloodvessels, and the ilio-inguinal nerve. The canal is a little above Poupart's ligament (inguinal ligament), and parallel with it. In front of the canal is the skin, the aponeuroses of the external oblique muscle, and a part of that of the internal oblique. Behind it are the reflected inguinal ligament, the transversalis fascia, the extraperitoneal connective tissue, and the peritoneum.

The diverging fibers of the external abdominal ring sometimes form a weak place in the abdominal wall.

Obliquus Internus Abdominis. (Figs. 168 and 170.)

Location.—In the second layer on the lateral wall of the abdomen.

Origin.—Outer half of Poupart's ligament; the middle lip of the anterior two-thirds of the crest of the ilium, and the lumbar fascia.

Insertion.—Lower border of the cartilages of the six lower ribs; ensiform process; linea alba; crest of the os pubis and iliopectineal line.

Nerve Supply.—Lower intercostals, ilioinguinal and iliohypogastric.

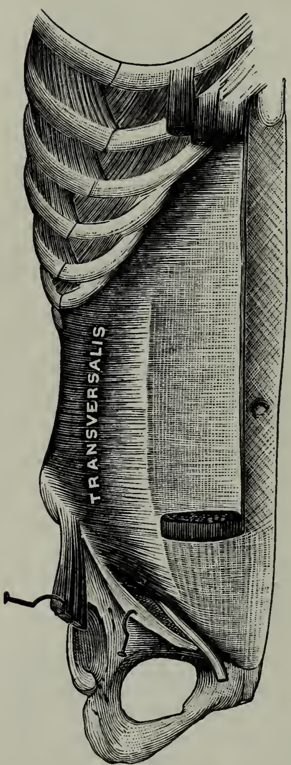


Fig. 171.—Transversalis (or Transversus) abdominis of right side. (Testut.)

Action.—Depresses the thorax; compresses the abdominal viscera; flexes the spine; side bend and rotate to same side, when only one side acts; and when thorax is fixed, flexes and rotates the pelvis to the opposite side.

Transversus Abdominis. (Fig. 171.)

Location.—Deep in the lateral wall of the abdomen.

Origin.—Inner side of the cartilages of the six lower ribs; inner lip of the iliac crest; lateral half of Poupart's ligament and the lumbar fascia.

Insertion.—Linea alba; iliopectineal line and crest of the pubis, by the conjoined tendon of itself and that of the internus.

Nerve Supply.—Lower intercostals, ilioinguinal and iliohypogastric.

Action.—Mainly to compress the abdominal viscera. May aid in expiration by contracting the thorax.

Quadratus Lumborum. (Fig. 144.)

Location.—Deep in the posterior wall of the abdomen.

Origin.—Inner lip of the iliac crest; transverse processes of three or four lumbar vertebræ; iliolumbar ligament and lumbodorsal fascia.

Insertion.—Last rib; transverse processes of three or four lumbar vertebræ.

Nerve Supply.—First three or four lumbar.

Action.—Lateral flexion of the spine; both acting together, extends spine; depresses and flexes the twelfth rib, in forced expiration.

THE MUSCLES OF THE THORAX.

Diaphragm	Levatores costarem
Intercostales externi	Triangularis sterni
Intercostales interni	Subcostales

Diaphragm. (Fig. 172.)

Location.—A dome-shaped muscle separating the thoracic and abdominal cavities, forming the floor of the first and the roof of the latter.

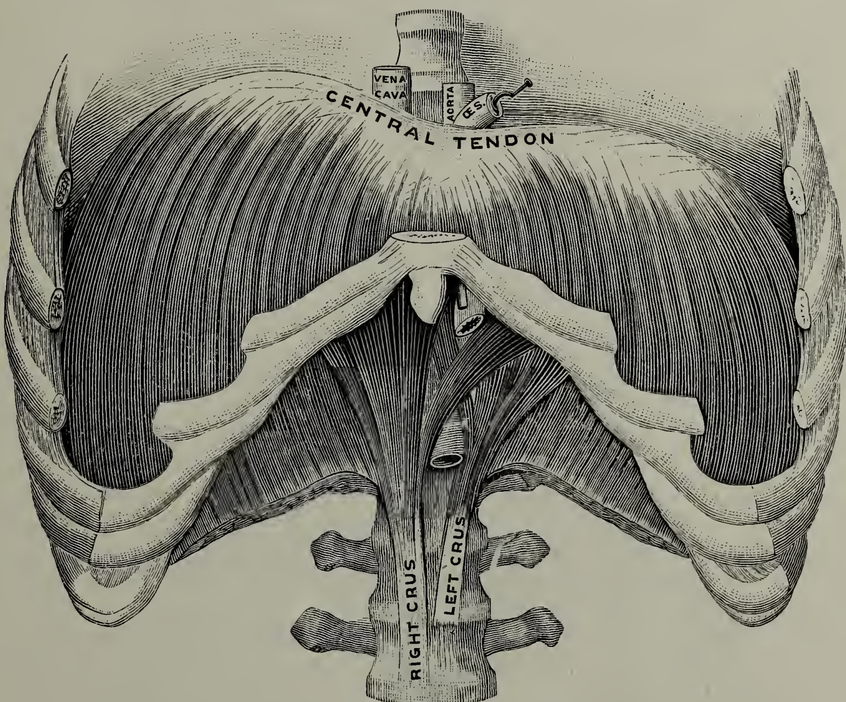


Fig. 172.—Diaphragm, viewed from in front. (Testut.)

Origin.—From the front of the bodies of the upper two lumbar vertebræ (four vertebræ on the right side), and the intervertebral disks, two *crura* are formed which arch over from one side to the other, and form an opening through which passes the aorta, the azygos vein, and the thoracic duct, just in front of the vertebral column. Anterior to this are openings for the passage of the esophagus with the vagus, and the inferior vena cava, with the right phrenic nerve.

The ligamentum arcuatum internum, forms a fibrous band which passes from the body of the first lumbar vertebra to the tip of its transverse process, while the ligamentum arcuatum externum passes from the tip of the transverse process to the last rib. These arch over the psoas magnus and the quadratus lumborum, respectively. Muscular fibers come from the inner surface of cartilages of the six lower ribs, interdigitating with the transversus, and to the ensiform process.

Insertion.—The muscle fibers converge to a central, three-leaved tendon. The pericardium is attached to its upper surface.

Nerve Supply.—The phrenic, from the cervical plexus, and fibers from the five or six lower intercostal nerves.

Action.—Flattens the arch of the dome, so increasing the vertical diameter of the thorax, by which means inspiration follows. It is the principal muscle of inspiration. Exerts pressure upon the abdominal organs if the front abdominal wall is not flaccid. Muscles which act at the same time as the diaphragm in respiration are classed as inspiratory muscles. The diaphragm adds power to expulsive acts, as sneezing, laughing, coughing, and vomiting. Its contraction induces a deep inspiration as preliminary to the expulsion of feces, urine, or the fetus.

The height of the dome varies in different positions of the body. In supine lying, it is highest, and makes the greatest excursion in normal respiration. In the erect position, the dome is lower, lower still in the sitting position. When lying on the side, the lower half is lower than in the sitting position, while the upper half is higher than in the supine lying.

The rhythmic up-and-down movement of the diaphragm exerts on the abdominal viscera a pressure similar to the intermittent pressure of massage. The diaphragm supports the organs within the thorax. The organs below this muscle depend upon two factors for their support. (1) ligaments attaching them to the spinal column; (2) the tonicity of the muscles of the anterior and lateral walls.

When these muscles become lax, the weight of the abdominal organs presses upon the pelvic contents and all sag. The effect of this pressure is increased by the increased lumbar curve, and the consequent lesser angle of the inlet plane of the true pelvis. This change in angle causes the inlet to face more nearly horizontally. (Fig. 82.)

Intercostales externi are on the outer wall of the thorax, passing

between the ribs, while the **intercostales interni** are on the inner wall, filling in the spaces between the ribs. The *externi* raise the ribs, and are assisted by the *levatores costarum,* possibly, but the action of the *interni* is not agreed upon. (Fig. 127.) It is asserted that the action of both internal and external intercostals is limited to preventing the spaces between the ribs being drawn in or pushed out during respiration.

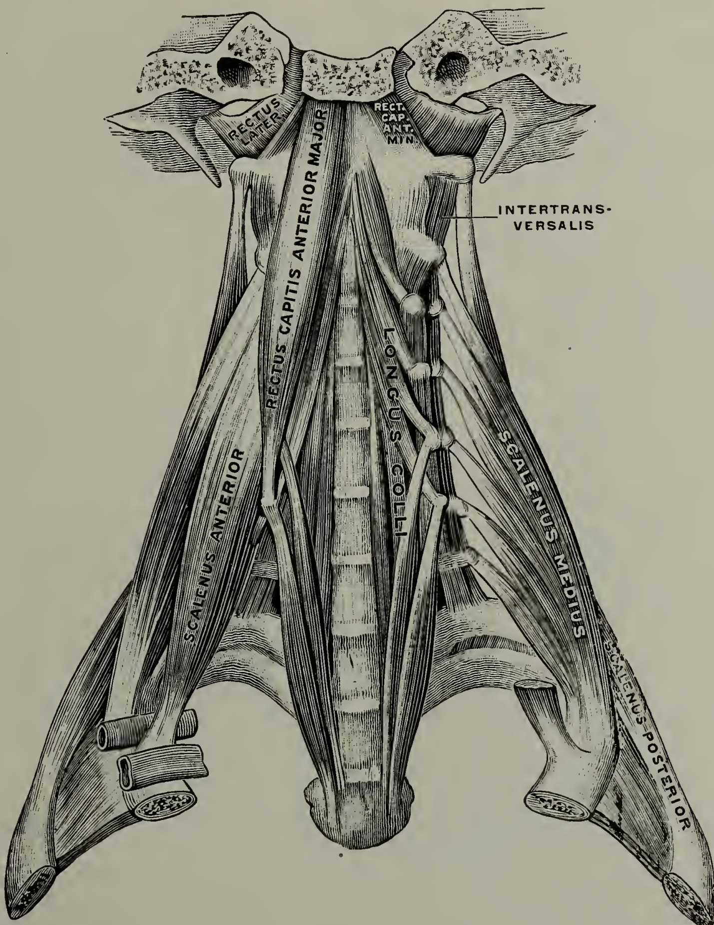


FIG. 173.—Deep lateral and prevertebral muscles of the neck. (Testut.)

The **Levatores costarum** pass between the transverse processes of the thoracic vertebræ and the dorsal surface of the rib below.

Triangularis sterni is a small triangular shaped muscle on the inner side of the thoracic wall in front. It depresses the ribs to whose cartilages it is attached.

Subcostales are small muscles, near the angle of the ribs, on the inner surface of the thorax. Their action is not well determined. The nerve supply of the above group of muscles are the respective intercostal nerves in their vicinity.

Although not on the thorax, several other muscles which have to do with respiration may be considered here. Located on the side of the neck, they act upon the upper ribs.

Scalenus Anterior.—(O. T. Scalenus anticus.) (Fig. 173.) Originating from the anterior tubercles of the transverse processes of the third to the sixth cervical vertebræ, the fibers are inserted on the upper surface of the first rib. Its action is to elevate that rib, and with the other two scaleni provide a basis for the intercostals to act in inspiratory lifting of the chest. The three scaleni are located back of the sterno-mastoid.

Scalenus Medius. (Fig. 173.)—An origin from the transverse processes of all the cervical vertebræ, and insertion into the upper surface of the first rib, gives this muscle the same action as the preceding.

Scalenus Posterior.—(O. T. Scalenus posticus.) (Fig. 173.) Coming from the transverse processes of the lower two or three cervical vertebræ, it is inserted into the outer surface of the second rib in front of the angle. Action, a part of the group as above.

The nerve supply of the group is from the cervical nerves from the second to the seventh.

THE MUSCLES OF THE HEAD AND NECK.

Sterno-cleido-mastoideus. (Fig. 174.)

Location.—Superficial on the front and side of the neck.

Origin.—The inner third of the upper border of the clavicle, and the upper border of the sternum.

Insertion.—Mastoid process of the temporal bone; outer half of the superior curved line of the occipital bone.

Nerve Supply.—Spinal accessory and second cervical.

Action.—When one side acts, it draws the head to the same side, and turns the face to the opposite side. When both muscles act, they flex the cervical portion of the spine, if the body is supine. In the erect position, gravity will do this without the contraction of the muscle. They draw the head backward, in association with the trapezius.

Platysma. (Fig. 175.)—A thin sheet of fibers passing between the clavicle and the chin, drawing down the angle of the mouth and the lower lip, and contracting the skin of the neck.

A group of muscles, some above, some below the hyoid bone, and connecting the latter with the lower jaw or the upper part of the

thorax, need be mentioned only. Their function has largely to do with deglutition.

Digastricus. (Fig. 174)
Stylohyoideus. (Fig. 174)
Mylohyoideus. (Fig. 174)
Geniohyoideus.

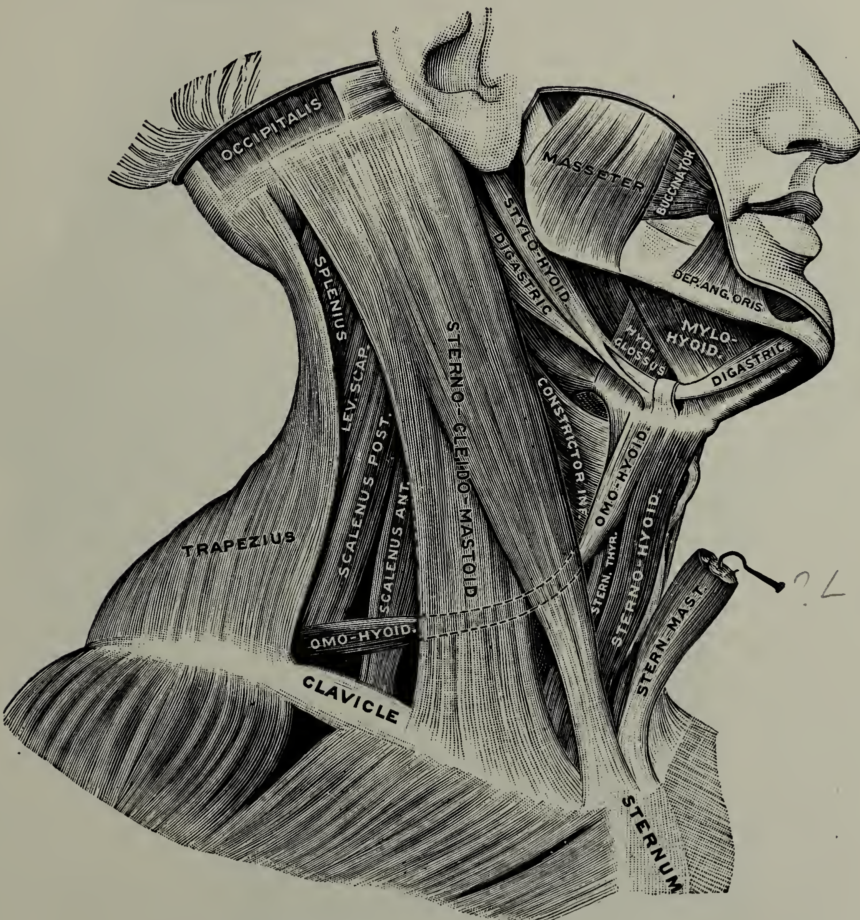


Fig. 174.—Muscles in front and side of neck. (Testut.)

The first four are situated above the hyoid bone, which they raise. The base of the tongue is raised with it, when food is sent from the mouth into the pharynx. When food is passing through the pharynx these muscles help to prevent its return to the mouth.

The second group of four depress the larynx and hyoid after the act of swallowing.

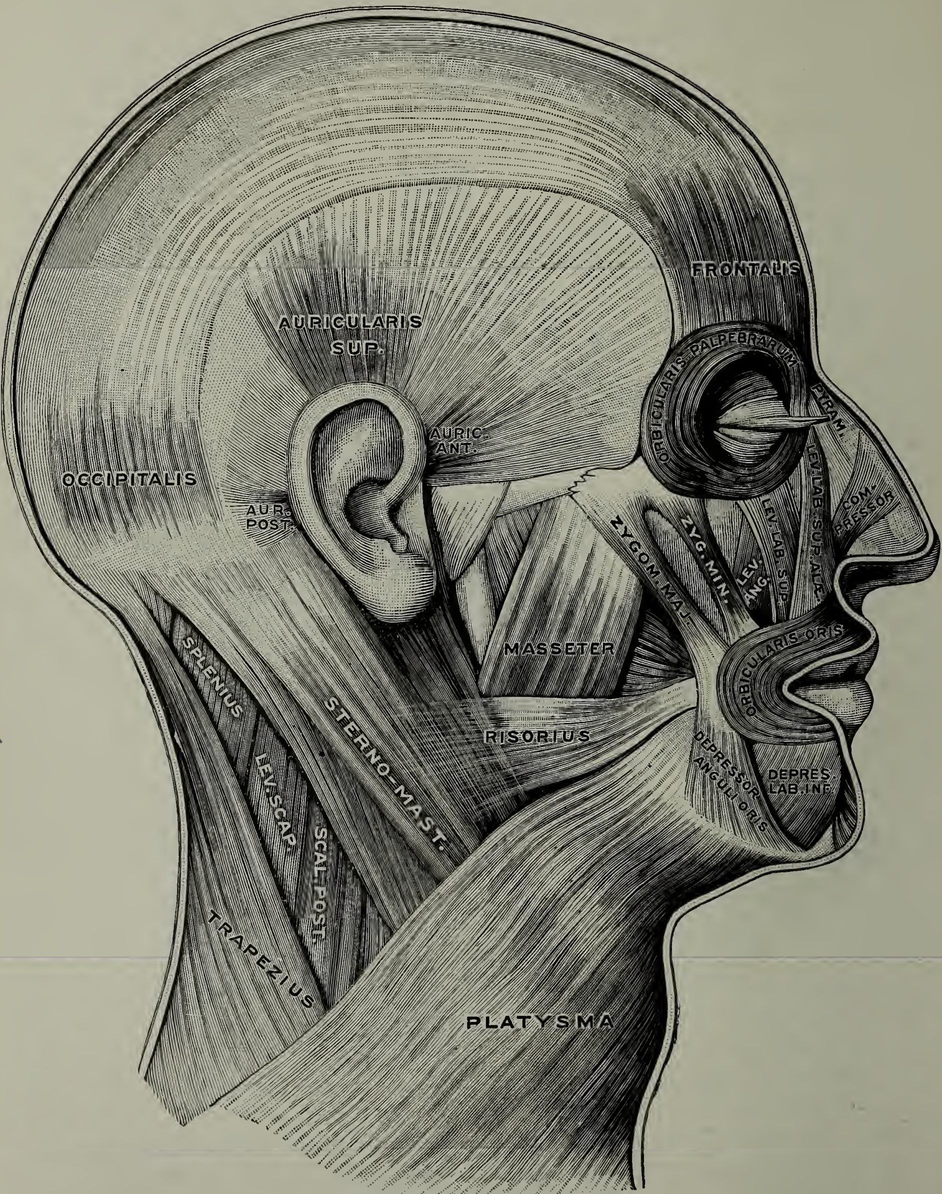


Fig. 175.—Superficial muscles of head and neck. (Testut.)

Sternohyoideus. (Fig. 174)
Omohyoideus. (Fig. 174)
Sternothyroideus. (Fig. 174)
Thyrohyoideus.

A group of muscles, deep in the front of the neck, of which the first bends the neck sideways, and the others flex it forward, are,

Rectus capitis lateralis. (Fig. 173)
Rectus capitis anterior major. (Fig. 173)
Rectus capitis anterior minor. (Fig. 173)
Longus colli. (Fig. 173)

The last group of muscles to be considered are those of expression and of mastication. They are superficial on the head, and a study of the illustrations with their names will be sufficient.

Muscles of Expression.—All supplied by the facial nerve.

Those affecting the orifice of the mouth.

Orbicularis oris. (Fig. 175)
Levator labii superioris alæque nasi. (Fig. 175)
Levator labii superioris proprius. (Fig. 175)
Zygomaticus minor. (Fig. 175)
Zygomaticus major. (Fig. 175)
Levator anguli oris. (Fig. 175)
Risorius. (Fig. 175)
Buccinator. (Fig. 175)
Depressor anguli oris. (Fig. 175)
Depressor labii inferioris. (Fig. 175)
Levator labii inferioris. (Fig. 175)

Those of the nose.

Pyramidalis nasi. (Fig. 175)
Compressor naris. (Fig. 174)
Levator labii superioris alæque nasi. (Fig. 175)
Depressor alæ nasi.

Those of the eyelids.

Orbicularis palpebrarum. (Fig. 175)
Tensor tarsi
Levator palpebræ

Those of the forehead.

Corrugator supercilii
Frontalis. (Fig. 175)

Of the occiput.

Occipitalis. (Fig. 174)

Muscles of Mastication.—Supplied by the trifacial or fifth cranial, nerve.

Masseter. (Figs. 174, 175)
Temporalis.
Pterygoideus internus
Pterygoideus externus

GROUPING OF MUSCLES ACCORDING TO FUNCTION.

(Based Upon Morris' Human Anatomy.)

In the following table only the principal muscles are considered, omitting those given but brief mention.

Muscles Acting on the Head.

To Flex It.—The supra- and infrahyoid muscles; rectus capitis anterior major and minor.

To Extend It.—Sterno-cleido-mastoideus, trapezius, splenius capitis, trachelo-mastoideus, complexus, obliquus capitis superior, rectus capitis superior major and minor.

To Bend to Side.—Sterno-cleido-mastoideus, rectus capitis lateralis, splenius capitis, trachelo-mastoideus, complexus, obliquus capitis superior.

To Rotate It.—Sterno-cleido-mastoideus, trapezius, splenius capitis, trachelo-mastoideus, complexus, obliquus capitis superior and inferior, rectus capitis superior major and minor.

Muscles Acting on the Spinal Column.

To Flex It.—Sterno-cleido-mastoideus, longus colli, rectus capitis anterior major, psoas magnus, scaleni, rectus abdominis, obliquus externus and internus abdominis.

To Extend It.—Splenius capitis, splenius cervicis, erector spinæ, semispinalis dorsi and cervicis, complexus, multifidus, rotatores, interspinales, levatores costarum and quadratus lumborum.

To Bend It Laterally and Rotate.—Sterno-cleido-mastoideus, scaleni, longus colli, trapezius, levator scapulæ, splenius capitis and cervicis, semispinalis dorsi, and cervicis, complexus, multifidus, rotatores, intertransversales, levatores costarum, psoas magnus, quadratus lumborum, obliquus externus and internus abdominis, rectus abdominis.

Muscles of Respiration.

Quiet Inspiration.—External intercostals, anterior internal intercostals, diaphragm.

Forced Inspiration.—The above, and the scaleni, sterno-cleido-mastoideus, serratus posterior-superior and inferior, rhomboids, serratus magnus, latissimus dorsi, pectoralis major and minor, and the extensors of the spinal column.

Quiet Expiration.—Posterior part of internal intercostals, subcostales, triangularis sterni.

Forced Expiration.—The above and the abdominal muscles, erector spinæ, and quadratus lumborum.

Muscles Acting on the Shoulder-girdle.

Elevation. — Levator scapulæ, trapezius, sterno-cleido-mastoideus, rhomboidei, serratus magnus, omo-hyoideus.

Depression.—Trapezius (lower part) pectoralis major (lower part) pectoralis minor, subclavius, latissimus dorsi.

Abduction.—Serratus magnus, pectoralis major and minor.

Adduction.—Trapezius, rhomboidei, latissimus dorsi.

Rotation, with Abduction of Arm.—Serratus magnus (lower part), trapezius, upper part, levator scapulæ.

Rotation with Adduction of Arm.—Rhomboidei, trapezius (lower part), serratus magnus (upper part), pectoralis major (lower part), and latissimus dorsi.

Muscles Acting on the Arm at the Shoulder-joint.

Abduction.—Deltoideus, supraspinatus, biceps (long head), pectoralis major.

Adduction.—Pectoralis major, latissimus dorsi, teres major, coraco-brachialis, long head of triceps.

Flexion.—Pectoralis major, deltoideus (clavicular portion), subscapularis, coraco-brachialis, biceps (short head), and serratus magnus.

Extension.—Deltoideus (posterior part), teres major, latissimus dorsi.

Outward Rotation.—Infraspinatus, teres minor.

Inward Rotation.—Subscapularis, deltoideus (anterior part), teres major, latissimus dorsi, and pectoralis major.

Muscles Acting on the Forearm.

Flexion (Forearm Supinated.)—Brachialis, biceps (long head), brachio-radialis, biceps (short head), extensor carpi radialis longus, pronator teres, flexor carpi radialis, extensor carpi radialis brevis, palmaris longus.

Flexion (Forearm Pronated or in Mid-position.)—Brachialis, brachio-radialis, biceps, extensor carpi radialis longus and brevis, pronator teres, flexor carpi radialis and palmaris longus.

Extension.—Triceps and anconeus.

Pronation of Forearm (Forearm Extended.)—Pronator teres, flexor carpi radialis, pronator quadratus, palmaris longus.

Pronation of Forearm (Forearm at Right Angles.)—Pronator teres, brachio-radialis, flexor carpi radialis, pronator quadratus, extensor carpi radialis longus and palmaris longus.

Pronation of Forearm (Forearm Flexed.)—Pronator teres and quadratus, brachio-radialis, flexor carpi radialis, extensor carpi radialis longus, and palmaris longus.

Supination of Forearm (Forearm Extended).—Brachio-radialis, biceps, supinator, extensor carpi radialis longus, abductor pollicis longus, extensor pollicis brevis and longus, extensor indices.

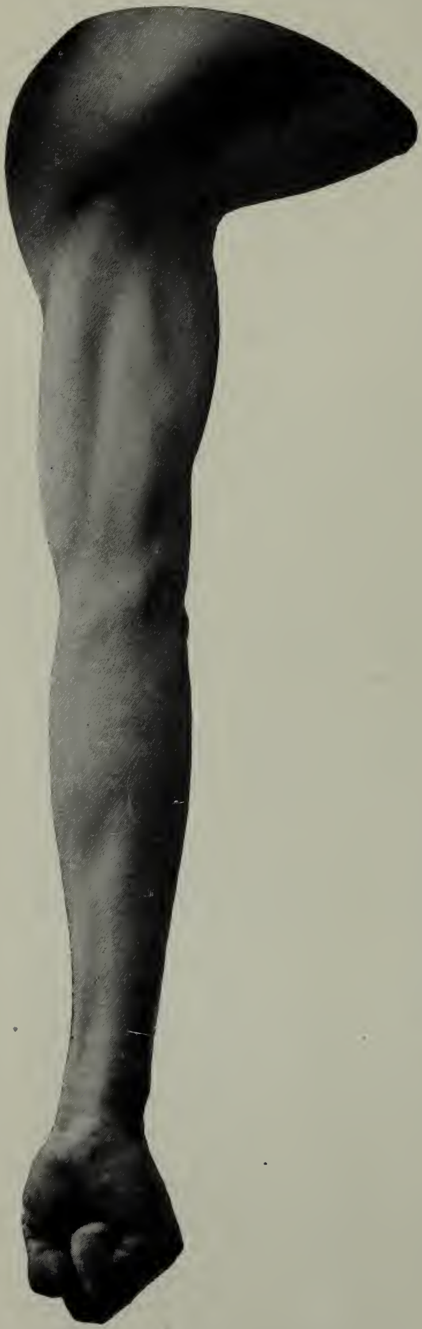


Fig. 176.—The right upper limb abducted and supinated, viewed from in front. (Gerrish.)

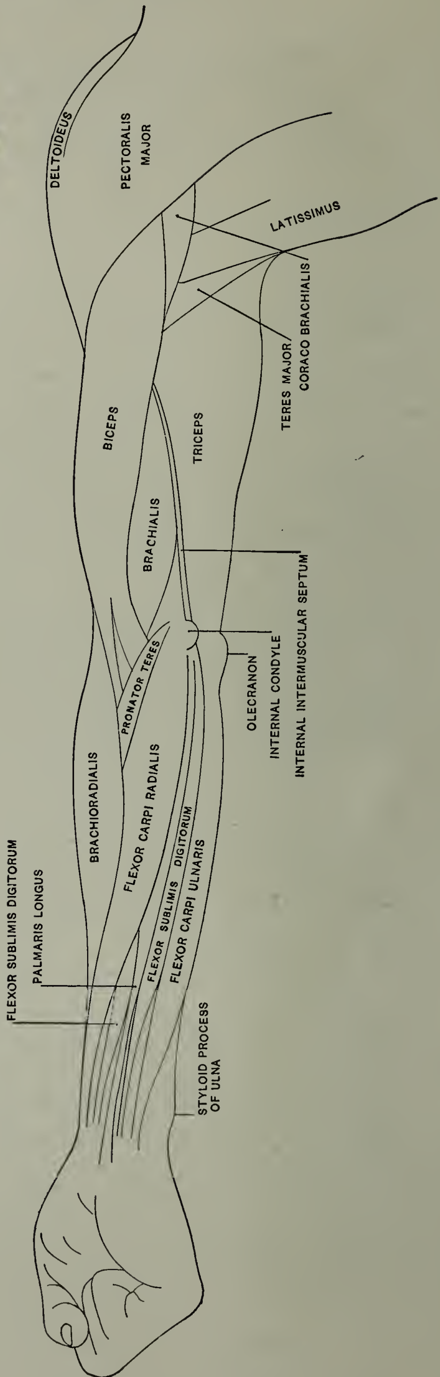


Fig. 177.—Key to Fig. 176. (Gerrish.)

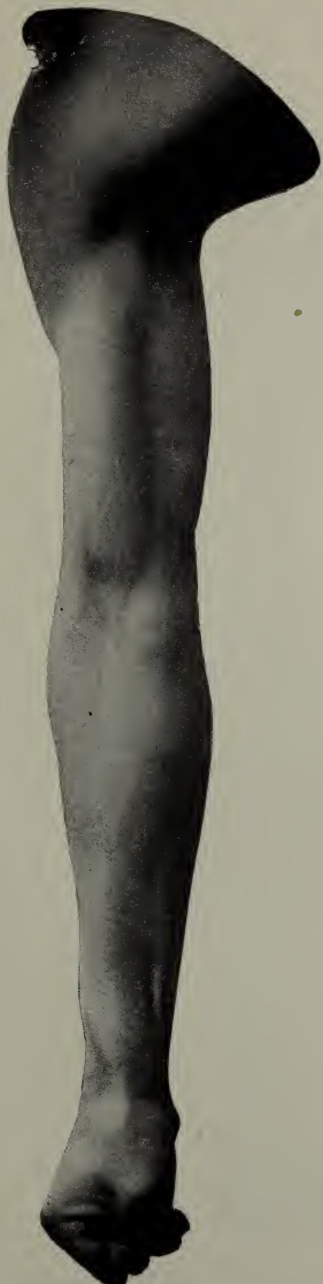


FIG. 178.—The right upper limb abducted and pronated, viewed from in front. (Gerrish.)

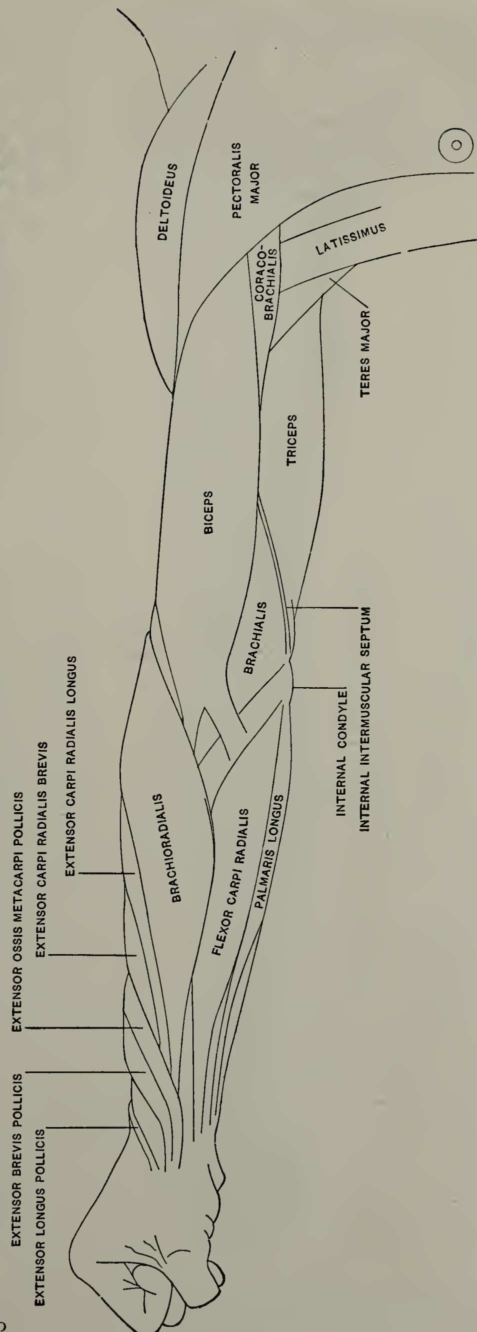


FIG. 179.—Key to Fig. 178. (Gerrish.)

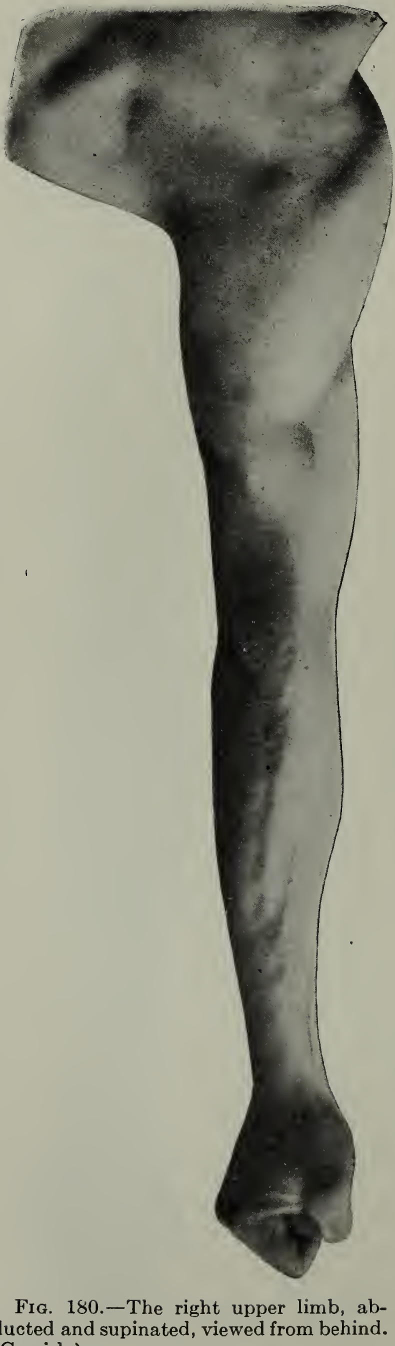


FIG. 180.—The right upper limb, abducted and supinated, viewed from behind. (Gerrish.)

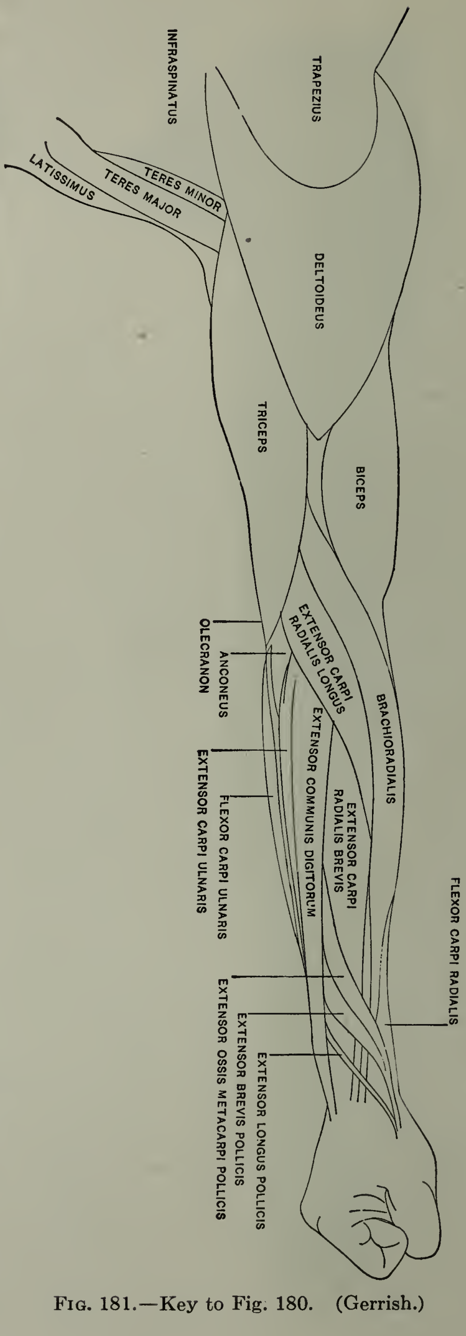


FIG. 181.—Key to Fig. 180. (Gerrish.)

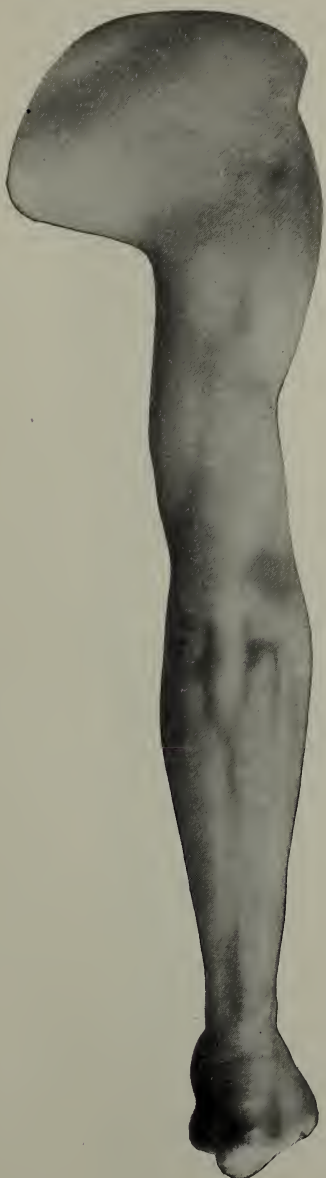


Fig. 182.—The right upper limb, abducted and pronated, viewed from behind. (Gerrish.)

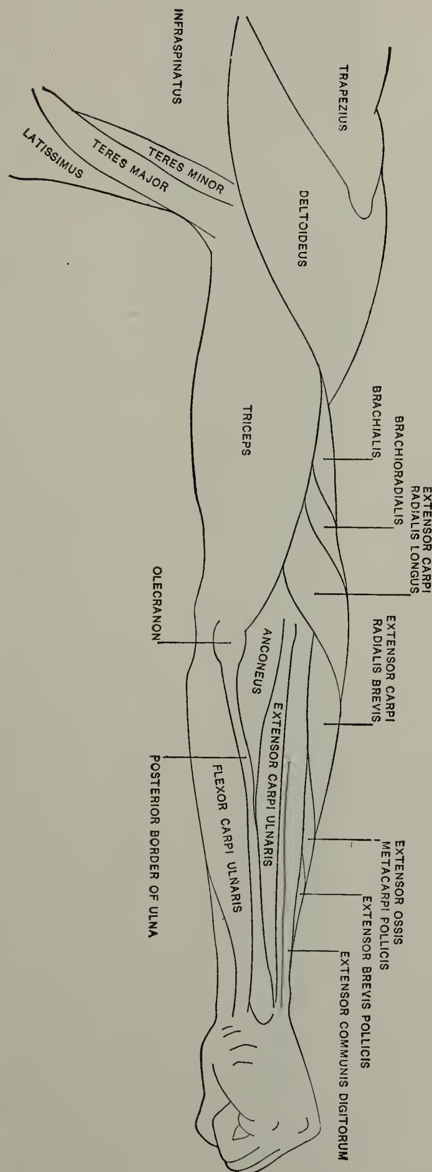


Fig. 183.—Key to Fig. 182. (Gerrish.)

Fig. 184.—The right lower limb, front view. (Gerrish.)

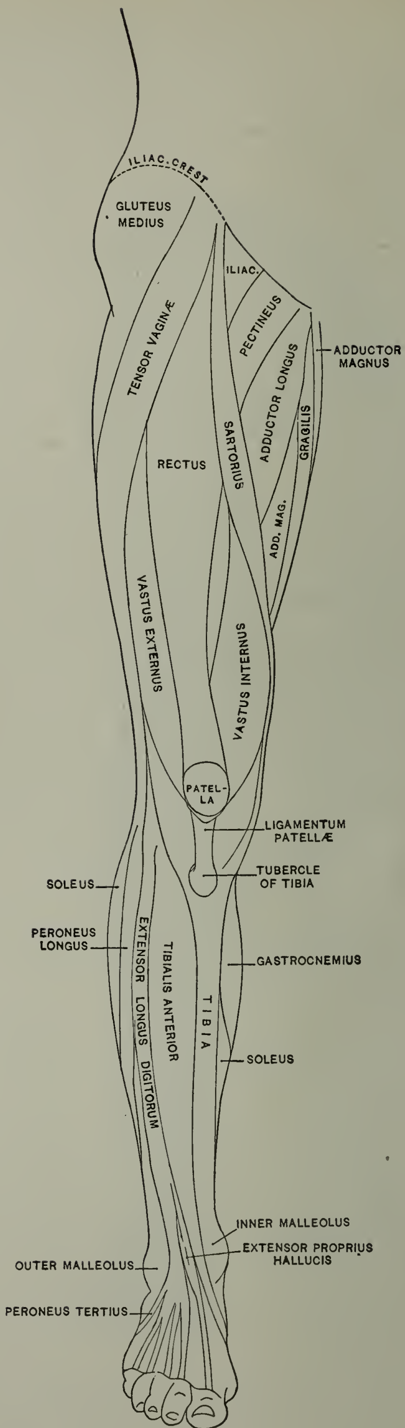


Fig. 185.—Key to Fig. 184. (Gerrish.)

Fig. 186.—The right lower limb, rear view. (Gerrish.)

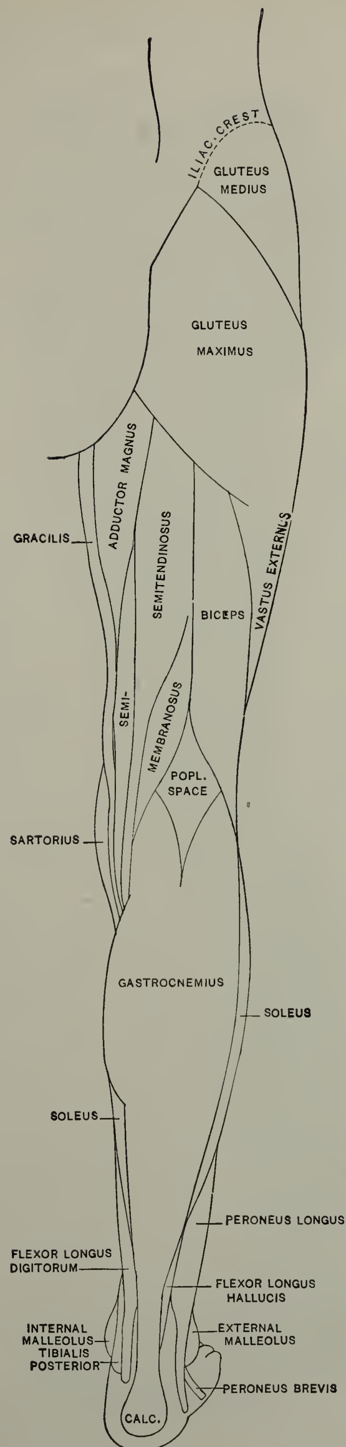


Fig. 187.—Key to Fig. 186. (Gerrish.)

Fig. 188.—The right lower limb, external lateral view. (Gerrish.)

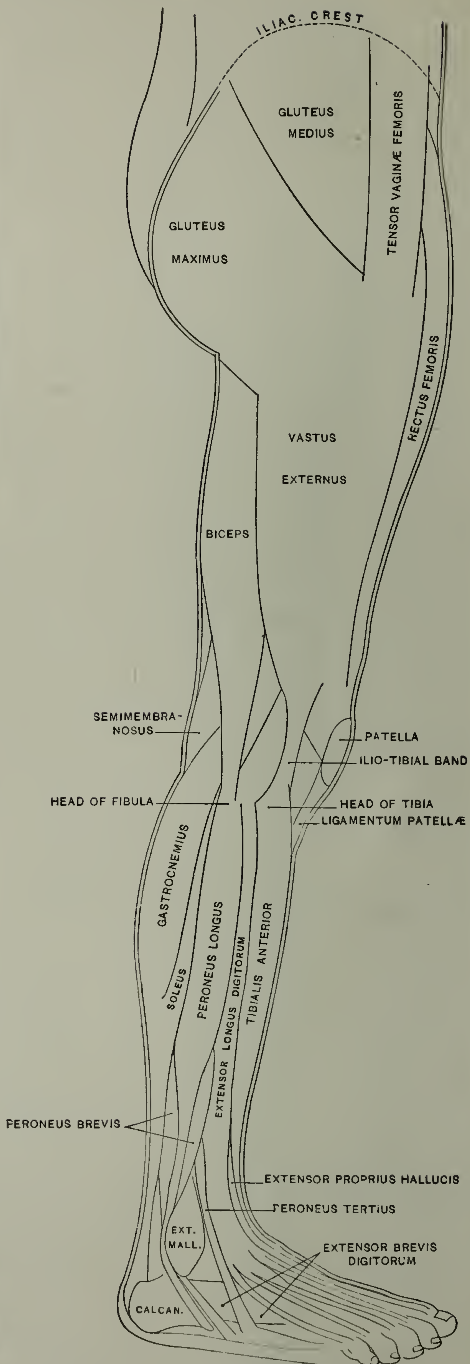


Fig. 189.—Key to Fig. 188. (Gerrish.)

Muscles Acting on the Forearm.—(*Continued*)

Supination of Forearm (Forearm Flexed.)—Biceps, supinator, extensor longus and brevis pollicis, extensor indicis, abductor pollicis longus (extensor ossis metacarpi pollicis).

Muscles Acting on the Hand at the Wrist.

Flexion.—Flexor carpi radialis and ulnaris, palmaris longus, the long flexors of the fingers and thumb.

Extension.—Extensor carpi radialis longus and brevis, extensor carpi ulnaris, and the extensors of the fingers and thumb.

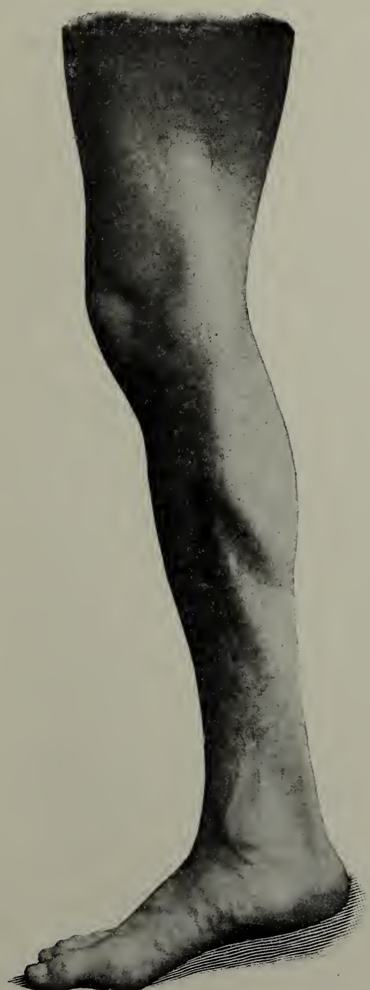


Fig. 190.—The right lower limb, internal lateral view. (Gerrish.)

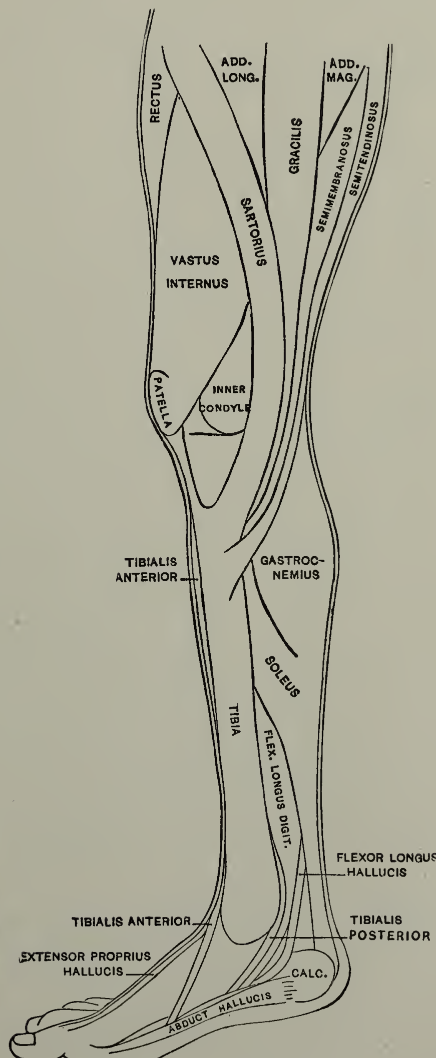


Fig. 191.—Key to Fig. 190. (Gerrish.)

Abduction.—Extensor carpi radialis longus and brevis, extensor ossis metacarpi pollicis, extensor brevis pollicis, flexor carpi radialis.

Adduction.—Flexor carpi ulnaris, extensor carpi ulnaris.

Muscles Acting on the Fingers.

Flexes All the Joints.—Flexor profundus digitorum.

Flexes All But the Last.—Flexor sublimis digitorum.

Flexes the First Only.—Flexor minimi digiti, lumbricales and interossei.

Extends the Fingers.—Extensor communis digitorum, extensor indicis, extensor minimi digiti.

Muscles Acting on the Thumb.

Flexes All Joints.—Flexor longus pollicis. The *carpo-metacarpal* joint, extensor ossis metacarpi pollicis, flexor ossis metacarpi pollicis.

Extends Both Joints.—Extensor longus pollicis.

Muscles Acting on the Pelvis.

Flexion.—Rectus abdominis, obliquus internus and externus abdominis, psoas magnus.

Extension.—Erector spinæ and multifidus.

Lateral Flexion with Rotation.—Rectus abdominis, obliquus internus and externus abdominis, quadratus lumborum, and psoas magnus acting on one side only.

Muscles Acting on the Thigh at the Hip-joint.

Flexion.—Iliopsoas, sartorius, rectus femoris, pectineus, gracilis, adductor longus and brevis, tensor fasciæ latæ.

Extension.—Gluteus maximus, biceps, semitendinosus, semimembranosus, adductor magnus.

Adduction.—Gracilis, pectineus, adductors magnus, longus and brevis, quadratus femoris, obturator externus, and lower part of gluteus maximus.

Abduction.—Gluteus medius and minimus, tensor fasciæ latæ, gluteus maximus, and when hip is flexed, pyriformis, obturator internus and gemelli.

Inward Rotation.—Tensor fasciæ latæ, gluteus medius and minimus, iliopsoas.

Outward Rotation.—Pyriformis, obturator externus and internus, gemelli, quadratus femoris, gluteus maximus and medius, sartorius, pectineus, adductor longus, brevis and magnus, biceps.

Muscles Acting on the Leg at the Knee-joint.

Flexion.—Sartorius, gracilis, semitendinosis, semimembranosus, biceps, gastrocnemius, popliteus.

Extension.—Quadriceps extensor cruris.

Inward Rotation (When Flexed.)—Sartorius, gracilis, semitendinosis, semimembranosus, popliteus.

Outward Rotation (When Flexed.)—Biceps femoris.

Muscles Acting on the Foot at the Ankle-joint.

Flexion.—Tibialis anterior, extensor longus digitorum, extensor longus hallucis, peroneus tertius.

Extension.—Soleus, gastrocnemius, flexor longus hallucis, peroneus longus and brevis, tibialis posterior, flexor longus digitorum.

Inversion at Medio-tarsal Joint.—Tibialis posterior and anterior.

Eversion at Medio-tarsal Joint.—Peroneus longus brevis and tertius.

NOTE.—The exact function of many muscles has not been determined decisively. What a muscle should do according to the law of mechanics is not always conclusive of what it really does, influenced by the action of antagonistic and fixator muscles.

Most of the muscles are placed in pairs, symmetrically on the two sides of the body, and the few that are described as single, have two sides. Some muscles are not constantly present, and in every cadaver something is likely to be lacking.

The number of muscles of the body, according to the differences in description, is given by varying authors as 400 to 622. Less then 100 pairs have been presented here as necessary for the student in physical education to really study and know.

QUESTIONS.

What muscles connect the head with the scapula?

What muscles connect the arm with the ribs?

What muscles connect the pelvis with the arm?

Name the flexors of the forearm.

Name the extensors of the thumb and fingers.

What muscles adduct the hand?

Name some muscles that pass over two joints.

What muscles extend the leg upon the thigh?

Name the adductor muscles of the thigh.

Which muscles extend one joint and flex the joint below or above?

Name the muscles that supinate the foot.

What is the action of the gluteus maximus?

On which surface of the tibia do the flexors of the foot find attachment?

Name the divisions of the erector spinæ, with a general description of the muscles.

What muscles form the abdominal wall?

Describe the diaphragm.

Compare the functions of the muscles of the upper extremity with those of the lower extremity.

Trace the outlines of muscles on yourself or on a fellow student by contracting same and noting boundaries. Observe any variation between those on the right and left sides.

Compare the forms of the Biceps Humeri and the Obliquus Externus Abdominis.

Why are they so different?

CHAPTER VI.

GENERAL CONSIDERATION OF BURSÆ AND FASCIÆ.

The small synovial sacs which are called bursæ are very numerous, but it is unnecessary to consider more than a limited number of them, or those that are at the larger joints.

In certain locations bursæ are always found, because they are needed to enable the muscle or tendon under which they are placed to function smoothly. (See page 119.)

Where an occupation causes an excessive amount of pressure over bone, bursæ may be developed in self-defense, as with cobblers who hold a stone on the thighs and pound their leather on it. This bursa develops between the rectus femoris and the vasti muscles. Or, as they hold the shoe against their breast-bone, there is a new bursa formed.

Persons who carry heavy burdens on their shoulders develop a bursa over the spine of the scapula, where the pressure is most marked.

The bursæ considered here are those in relation to the shoulder-elbow-, knee- and ankle-joints.

BURSÆ IN RELATION WITH THE SHOULDER-JOINT.

The *bursa trapezii,* is located between the trapezius muscle and the triangular space at the root of the spine of the scapula.

The *bursa acromialis subcutanea,* is placed between the acromion process and the skin over it.

The *bursa subacromialis* is between the capsular ligament of the shoulder-joint and the arch made by the coracoid and acromial processes, and extends beneath the deltoideus muscle. This is sometimes called the *bursa subdeltoidea.* This bursa is very liable to injury and inflammation, producing marked impairment in the use of the arm.

BURSÆ IN RELATION WITH THE ELBOW-JOINT.

The *bursa bicipito-radialis,* is placed between the tuberosity of the radius and the tendon of the biceps muscle.

The *bursa olecrani subcutanea,* is between the dorsal surface of the olecranon and the overlying skin.

BURSÆ IN RELATION WITH THE KNEE-JOINT.

A large number of bursæ exist about the knee-joint, of which the following should be noted.

The *bursa sartorii* is placed between the sartorius muscle, and the inner tuberosity of the tibia, separating the tendon of the sartorius from those of the gracilis and semitendinosus muscles.

The *bursa semimembranosus* is between the tendon of the semimembranosus muscle and the inner tuberosity of the tibia.

The *bursa tibialis interna* is placed between the internal lateral ligament of the knee-joint and the tendons of the inner hamstrings, sartorius, gracilis and semitendinosus muscles.

The *bursa bicipitis cruris* is between the external lateral ligament of the knee-joint and the tendon of the biceps femoris muscle.

The *bursæ poplitei* are placed between the origin of the popliteus muscle on the external condyle of the femur, the external tuberosity of the tibia and the capsular ligament of the knee-joint.

The *bursa suprapatellaris* is between the quadriceps extensor cruris muscle and the lower part of the shaft of the anterior surface of the femur.

The *bursa prepatellaris subcutanea* is located between the skin and the anterior surface of the patella.

The *bursa infrapatellaris* is placed between the ligamentum patellæ and the anterior surface of the upper part of the tibia.

The *bursa condyli externi* is between the external condyle of the femur and the skin.

The *bursa condyli interni* is between the internal condyle of the femur and the skin.

The *bursa pretibialis* is between the tubercle of the tibia and the overlying fascia.

BURSÆ IN RELATION WITH THE ANKLE-JOINT.

The *bursa postcalcanea profunda,* lies between the posterior surface of the os calcis and the tendo Achillis.

The *bursa malleoli externi subcutanea* is placed between the external malleolus and the skin.

The *bursa malleoli interni subcutanea* is between the internal malleolus and the skin.

THE FASCIÆ.

Fasciæ are fibrous sheets which are wrapped around various organs, especially muscles, serving to keep them in definite and intimate relation with each other. The term also includes certain strong fibers that connect bony parts.

The fasciæ include two varieties, superficial and deep. The

typical superficial fascia is the continuous layer of areolar tissue directly under the skin, connecting and separating the skin from the deeper structures, including the deep fascia. It contains fat cells, forms a bed for bloodvessels, and nerves on their way to and from various organs. It is also a factor in preserving the body temperature, as the contained fat (sometimes in great quantity) is a poor conductor of heat. There is much variation in the thickness of this superficial fascia, from a very thin and delicate membrane to the big-meshed and heavy structure. Over the abdomen and the buttocks the meshes are large, frequently holding an enormous accumulation of fat cells, even several inches thick. Except on the palms and soles, which are held firmly, the superficial fascia allows the skin to move with considerable freedom.

The deep fasciæ are strong, close sheets of white fibrous tissue. They appear as iridescent, pearly-white structures, very flexible and non-elastic. Sometimes they are really the spread-out tendon of a muscle. At times they serve as ligaments, and are generally in close association with other forms of fibrous tissue as tendons, periosteum, etc. While they sheathe muscles, they also pass between as *septa* and connect them.

While all the muscles are covered by fascia, in certain localities there is a thickening and accentuation of it. In the upper extremity at the wrist are transverse bands of fibers which are called *annular ligaments*, anterior and posterior respectively. They hold the tendons in place, keeping them from flying out, as they pass from the forearm into the hand. (Figs. 135, 137, pages 167, 171.) In the neck the strong cervical fascia is particularly well marked, covering the entire neck and dipping down between the various muscles, some of which it also covers.

On the palm of the hand the *palmar fascia* is particularly strong and dense. It is sometimes an expansion of the tendon of the palmaris longus. It gives protection to the nerves and bloodvessels in the palm and adds much to the strength of the "grip."

The *transversalis fascia* lies between the inner surface of the transversus abdominis and the extraperitoneal fat. It is part of the lining of the abdominal wall, and unites with the fibers covering the lower surface of the diaphragm.

The *lumbar fascia* is essentially a combination of spread-out tendons, though it also covers some muscles as a sheath. Fig. 170, page 211. The tendons of the latissimus, serratus posterior inferior, obliquus internus abdominis, and transversus abdominis muscles help to form this fascia, though they are frequently described as arising from it. It is attached to the spines and transverse processes of the lumbar and sacral vertebræ, to the last rib and to the outer lip of the posterior third of the crest of the ilium. It forms three layers, and invests as a sheath the quadratus lumborum and

erector spinæ muscles, besides giving attachment to them. On the thigh, the superficial fascia covers the entire surface. Much fat is in the areolar meshes. The fascia can be separated into two layers, between which are the superficial bloodvessels and nerves.

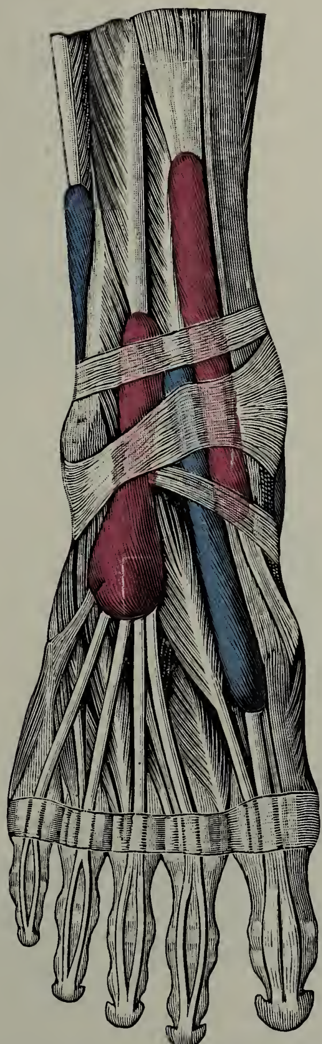


Fig. 192.—The anterior annular ligament of the ankle and the synovial membranes of the tendons beneath it artificially distended. (Testut.)

The Fascia Lata.—The fascia lata is a very strong and dense sheath covering the entire musculature of the thigh, and sending some fibers to help make the capsular ligament of the knee-joint.

It is a single layer in most of its extent, but splits so as to encase the gluteus maximus and the tensor fascia lata muscles. It is more

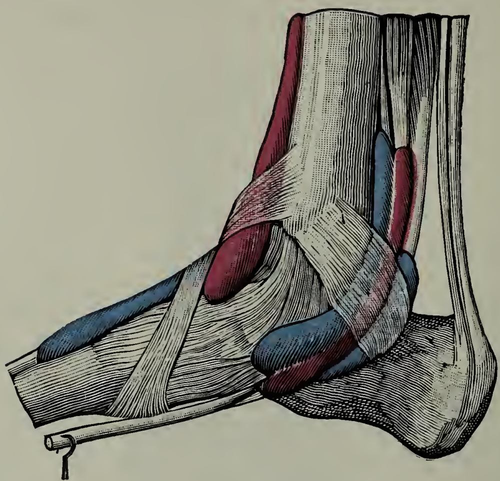


Fig. 193.—The internal annular ligament of the ankle and the artificially distended synovial membranes of the tendons which it confines. (Testut.)

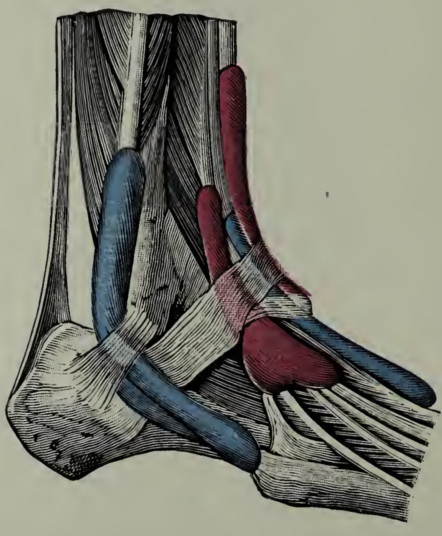


Fig. 194.—The external annular ligament of the ankle and the artificially distended synovial membrane of the tendons which it confines. (Testut.)

dense on the outer aspect of the thigh, where it is continued downward to the lateral condyle of the tibia as the *iliotibial band.* Two septa between the vastus lateralis and the biceps are attached to

the *linea aspera.* Numerous smaller septa separate other muscles and enclose them in individual sheaths.

The contraction of the tensor fasciæ latæ tightens this fascia and adds much to the efficiency of the other muscles of the thigh.

Annular Ligaments of the Ankle.—At the ankle, transverse bands of fibers form an annular ligament to hold the tendons which pass into the foot from flying out when their muscles contract. There are three divisions of the ligament, anterior, internal and external.

The anterior annular ligament holds down the tendons of the extensor longus digitorum, peroneus tertius, tibialis anterior, and extensor proprius hallucis muscles (Fig. 192).

The internal annular ligament holds down the tendons of tibialis posterior, flexor longus digitorum, and flexor longus hallucis muscles (Fig. 193).

The external annular ligament holds down the tendons of the peroneus longus and peroneus brevis muscles (Fig. 194).

Plantar Fascia.—On the sole of the foot where the bloodvessels and nerves are peculiarly susceptible to injury in walking, the layer of fascia is very dense and thick. Transverse bands hold in place the tendons which move the toes.

Connection of Fasciæ and Veins.—In most of the joints of the body, but especially at the shoulder, lower part of the neck, the elbow-, knee- and hip-joints, the deep fascia is attached to the fibrous covering of the large veins in those regions.

When the joint is moved, the fascia is pulled. In turn it pulls upon the veins, opening out the latter and creating a partial vacuum. This is instantly filled by the rush of blood, thus serving as a suction pump in returning the venous blood to the heart. On account of the valves it cannot go in the opposite direction. When the pull is released, the veins return to their former caliber. This presses upon the blood, sending it along toward the heart. Thus the deep fasciæ serve an important use in the circulation of the blood.

QUESTIONS.

What is a bursa?

Where are bursæ placed?

What results from an inflammation of the bursa subacromialis?

What joint needs and has the greatest number of bursæ?

What is the "fascia lata?"

What is the "annular" ligament of the wrist?

What would probably result if there was no "annular" ligament of the ankle?

CHAPTER VII.

THE CEREBROSPINAL NERVOUS SYSTEM.

THE nervous system is divided into two parts, the *cerebrospinal* and the *sympathetic* or *autonomic*.

The cerebrospinal system is the seat of conscious knowledge, of will, of coördination, of thought, and of sensation. With this part of the nervous system we see, hear, taste, smell, feel, think. After assembling these sensations we make such responses by motion as the will ordains. Or, we even respond by motion without the will being concerned. All the so-called higher faculties are lodged in the cerebrospinal axis.

Anatomically, the cerebrospinal system consists of the cerebrospinal axis, the cranial, and spinal nerves.

The cerebrospinal axis consists of the brain or encephalon, and the spinal cord.

THE ANATOMY OF THE BRAIN.

The Encephalon.—The encephalon is contained in the cranial cavity, and weighs on an average about 3 pounds. It consists of four parts, the *cerebrum*, the *cerebellum*, the *pons varolii*, and the *medulla oblongata*.

The Meninges of the Brain.—The brain is covered by three membranes, the *pia mater*, the *arachnoid*, and the *dura mater*. These are called the *meninges*.

The *pia* is next to the brain substance, and is a very delicate network of small bloodvessels, supported by areolar tissue, carrying nutrition to the various parts of the surface. It dips down into the various fissures, following all the irregularities of the surface. The pia distributes an abundant supply of blood to the brain, which has come *via* the internal carotid and vertebral arteries. The blood supply to the brain has very few anastomoses. If any vessel is obstructed, there is little chance for other arteries to make up the deficiency to the area supplied by the obstructed artery.

The *dura* is a dense, strong, fibrous structure in two layers, which not only covers the brain, but serves as the periosteum of the cranial bones. These layers are closely united except in certain places. Small channels in the cranium are lined by the dura, and shelf-like processes of the inner layer project toward each other so that canals are formed which contain veins. These are called *sinuses*. (Fig. 195.) Prolongations of the dura serve to separate

parts of the brain. The *tentorium* is that horizontal prolongation between the cerebellum and the occipital portion of the cerebrum; the *falx cerebri* is between the two hemispheres, and the *falx cerebelli* separates the cerebellar hemispheres.

On the inner surface of the dura is a delicate layer of epithelial cells, with a similar layer on the outer surface of the pia. These form the arachnoid membrane, essentially a serous membrane, which bridges over irregularities of the brain surface, leaving spaces

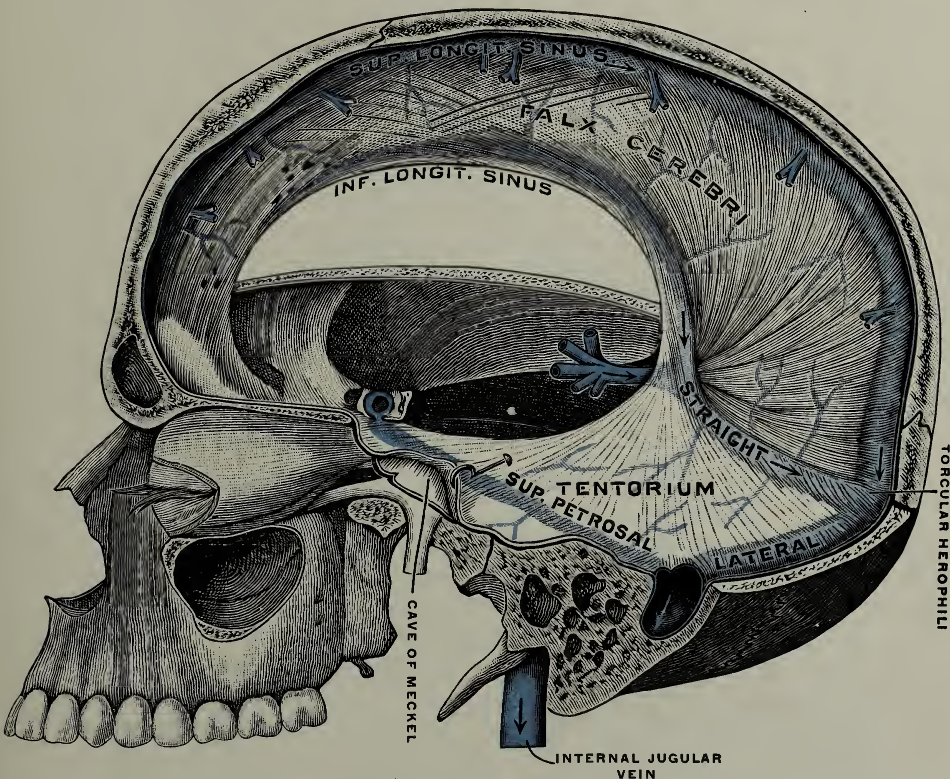


FIG. 195.—Sinuses of the dura, left lateral view. (Testut.)

which are filled with the cerebrospinal fluid. This fluid forms a water-bed between the brain and the bones of the cranium, lessening jar. The water-bed is the subarachnoid space, expanding at places near the base of the brain into the ventricles of the brain, (*sub-arachnoid cisterna*), which serve as reservoirs for excess of fluid. In them, what are known as the *choroid plexuses*, capillary tufts and peculiar epithelial cells, apparently form cerebrospinal fluid. Besides this source of the cerebrospinal fluid, are the *perivascular spaces* surrounding the bloodvessels penetrating the surface of the

brain. A layer of epithelial cells forms the boundary of these spaces. The fluid flows from the main ventricles into the third, then the fourth ventricle, from which by two apertures, it gets into the subarachnoid space. The brain is never completely at rest, being literally churned up and down by the varying amounts of blood going to it. The respiratory movements, by drawing blood into the heart, lessens the amount in the brain. The pulsations of the large arteries of the brain vary in force and frequency, sometimes being very rapid and strong. The jarring effects of these are minimized by the water-bed.

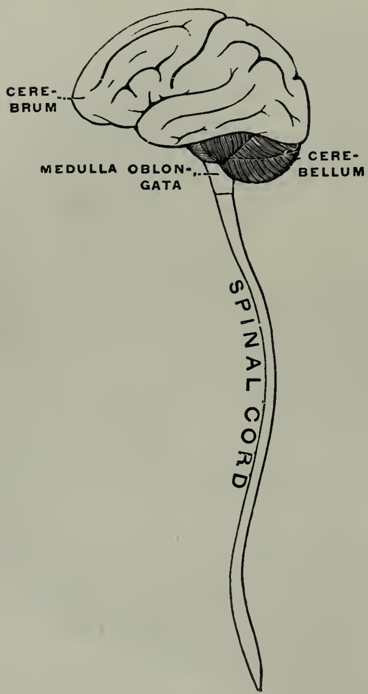


Fig. 196.—Semidiagrammatic view of the cerebrospinal axis, left side. (Testut.)

The varying amount of blood in the brain may be observed by watching the fontanelles on the head of an infant. Every time the child inspires, the skin covering the fontanelles sinks in, while during expiration there is a bulging outward.

The Divisions of the Brain.—The four divisions of the brain vary much in size. Largest of all is the *cerebrum*, or fore-brain, extending from the forehead to the occiput, and filling the vault of the cranium above the eyes and ears. It rests upon the floor of the cranium, leaving but a small compartment for the rest of the brain. It is divided into right and left hemispheres.

The second division in size is the *cerebellum*, or hind-brain. It occupies the back part of the base of the skull. (Fig. 196.) The tentorium forms a tent over the cerebellum and keeps the pressure of the posterior lobes of the cerebrum from it.

The *pons varolii* surmounts the medulla, and is the means by which the medulla is connected with the cerebrum and cerebellum. It is the cross-roads of the brain, resting on the base of the cranium just in front of the medulla. While there is some gray matter in the pons, it is mainly composed of fibers which run in various directions. One set, connecting the isthmus with the medulla, passes through the central part. Another set passes horizontally, connecting the two lateral hemispheres of the cerebellum. Several collections of

cells are among these fibers, including the nuclei, or places of origin, of the fifth, sixth, seventh, and eighth cranial nerves.

The *medulla oblongata* is virtually the upper end of the spinal cord expanded into a club-shaped process, and projected into the cranial cavity, resting on the base of the skull. A description of it will be found after the consideration of the cerebrum and cerebellum.

The Cortex.—The tissue of the brain is divided into gray and white matter, the gray matter representing the cellular or working element, and the white matter the communicating fibers.

The gray matter is on the outside of the brain, forming a layer about $\frac{1}{4}$ inch thick, which is called the *cortex*.

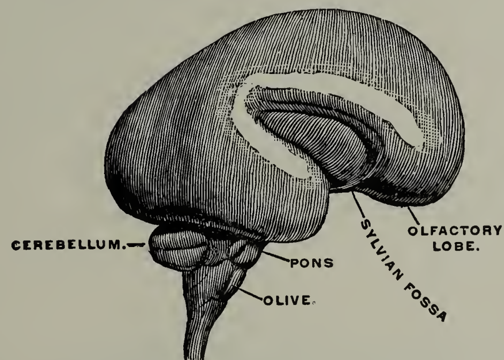


FIG. 197.—Brain of six-months' human embryo, natural size, right side. (Kölliker.)

This is an aggregation of neurons, with the axones leading out of the brain to some part of the periphery, but with the branching processes, or dendrites, in intimate association with their neighbors. As animals ascend in the scale of intelligence and brain power there is a change in the appearance of this layer of gray matter. This is illustrated by the human fetus, which at six months shows a perfectly smooth layer of gray matter in the cortex (Fig. 197), but shortly begins to show wrinkling and folds all over it. The wrinkles become deeper and more numerous as the brain develops and are called *fissures*. (Fig. 198.) Individuals are more able, not according to the size of their brains, but according to the depth and number of the wrinklings, and in the multitude of their association neurons.

This arrangement of wrinkling gives space for a vastly greater number of neurons than could be accommodated on a smooth surface. The fissures vary on the two sides of the brain and in different individuals, but correspond very constantly. (Fig. 199.) The space between the fissures is called gyrus or convolution.

The *longitudinal* fissure divides the cerebrum into lateral halves. The *Sylvian* fissure starts near the center of the base of the brain,

going upward and backward, then dividing into anterior and posterior limbs.

Above the Sylvian fissure in the middle region of the lateral surface is the *fissure of Rolando,* or the central fissure. It starts from the longitudinal fissure and passes downward almost to the Sylvian fissure.

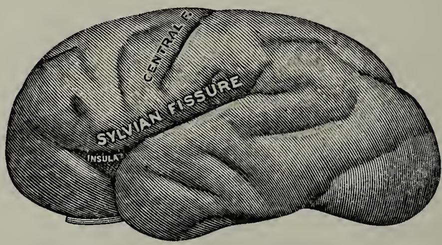


Fig. 198.—Cerebrum of eight-months' human embryo, left side. The insula is nearly covered in. (Testut.)

The *parieto-occipital* fissure begins far back on the upper margin of the hemisphere and continues downward and forward. These fissures mark, more or less accurately, the boundaries of four lobes of the brain, the *frontal, parietal, temporal,* and *occipital.* (Fig. 200.)

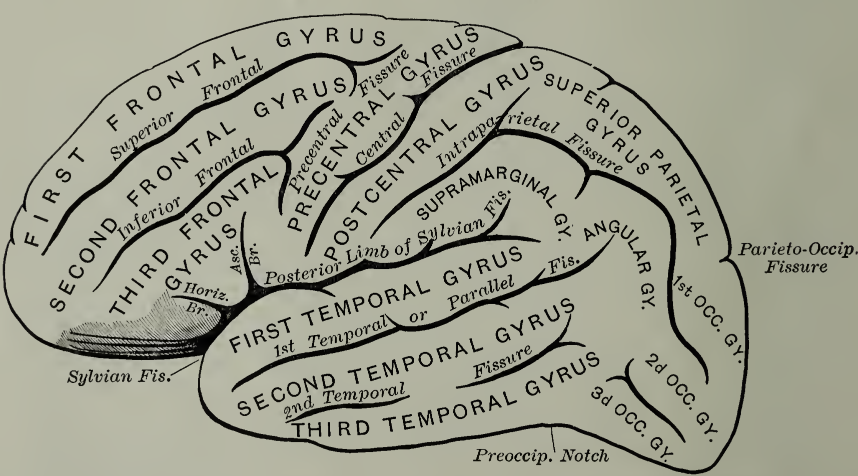


Fig. 199.—The gyri and fissures of the external lobes of the left hemisphere. (Gerrish.)

A fifth lobe, the *insula,* is scarcely visible from the surface because the other lobes develop so much faster they cover it from sight. A sixth lobe is the *limbic* or *falciform.* (Fig. 201.)

The major divisions of the cerebrum are these lobes. Smaller, more shallow fissures divide the lobes into gyri.

The Corpus Callosum.—Beneath the gray matter in the cerebrum is a large mass of white matter, the *corpus callosum.* It consists of medullated fibers which cross from one side of the brain to the other, from one part of a hemisphere to another part. (Fig. 202.)

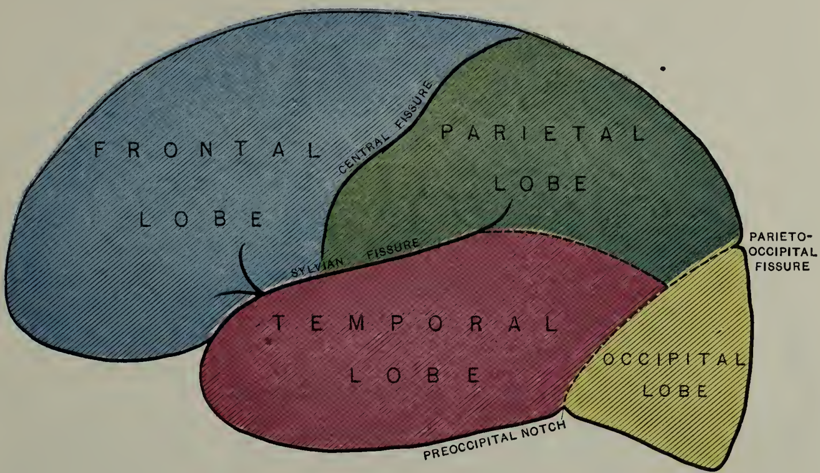


Fig. 200.—The lobes of the convex surface of the hemisphere, left side. (Gerrish.)

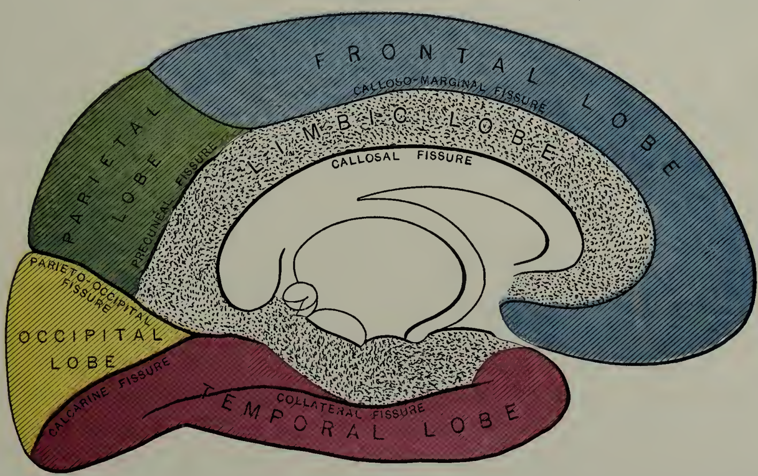


Fig. 201.—The lobes of the mesial and tentorial surfaces of the left hemisphere. (Gerrish.)

It is like a great flat band of nerve fibers which runs from side to side forming the roof of the ventricular space. By means of these, fibers the gray matter of one part of the cerebrum is held in close and constant communication with the gray matter of every other

part. The arrangement of the fibers is exceedingly intricate, as they pass in every possible direction. By means of these paths, impressions received from the outer world are coördinated with thought, emotion, and motor activity. Every voluntary movement of the body is a complex act. It is preceded or accompanied by certain sensations or perceptions which occur in some part of the brain, dependent upon stimulation of the sensory nerves in some way, or upon experience derived from former similar occurrences.

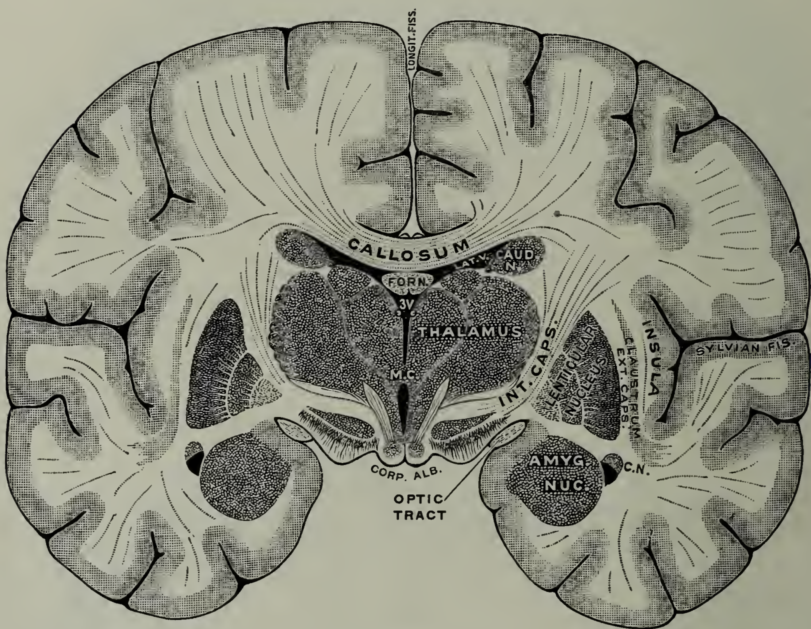


FIG. 202.—Coronal section of the hemispheres through the middle commissure: AMYG. NUC., amygdaloid nucleus; C.N., caudate nucleus in the roof of the middle horn of the right lateral ventricle; CORP. ALB., corpora albicantia; EXT. CAPS., external capsule; FORN., fornix; INT. CAPS., internal capsule; LAT. V., body of lateral ventricle; 3 V., third ventricle. (Testut.)

Some mental associations are developed, with activity over large areas of the cortex before the conscious orders go out from definite areas to the muscles. These orders are for certain contractions to occur that shall produce certain movements.

In the corpus callosum are various small masses of gray matter, some of which are called "nuclei," "ganglia," "commissures," etc. On the floor of the ventricles, and in the upper part of the medulla, other small gray masses are found. Many of the cranial nerves originate in these areas.

The Cerebellum.—The cerebellum, or hind-brain is in the posterior fossa of the cranium covered by the tentorium. Its gray matter is on the outside, projecting inward in tooth-like or dentate processes. Its main portion consists of three parts, a middle and two lateral divisions called hemispheres. The median portion, also called the vermis is very small, so it can be hardly seen. (Fig. 203.) The upper surface of the cerebellum is nearly flat (Fig. 204.) and the lower surface convex (Fig. 205).

Fissures on both surfaces run transversely, dividing the substance into layers, leaves or laminæ.

They are similar to the gyri of the cerebrum in having white

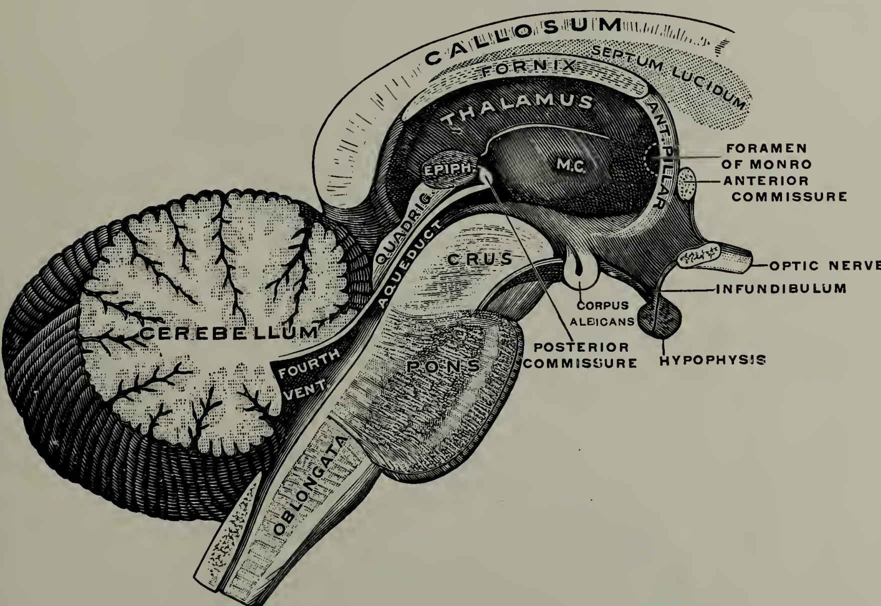


FIG. 203.—Median section through the third and fourth ventricles. Left half. M.C., middle commissure. (Testut.)

fibers in a mass below, covered with gray matter. The cerebellum is connected with the other parts of the brain by three pairs of bands. One pair goes to the medulla, one to the pons and the other pair to the mid-brain or isthmus. (The isthmus is a narrow neck by which the cerebellum is connected with the structures below.)

The Medulla Oblongata.—This is also known as the medulla or spinal bulb, and may be considered as a connecting link between the spinal cord and other parts of the brain. In its structure it presents similarities to both.

The medulla rests upon the basilar process of the occipital bone, is about $1\frac{1}{4}$ inches long, extending from the lower margin of the pons to the beginning of the spinal cord just below the "decus-

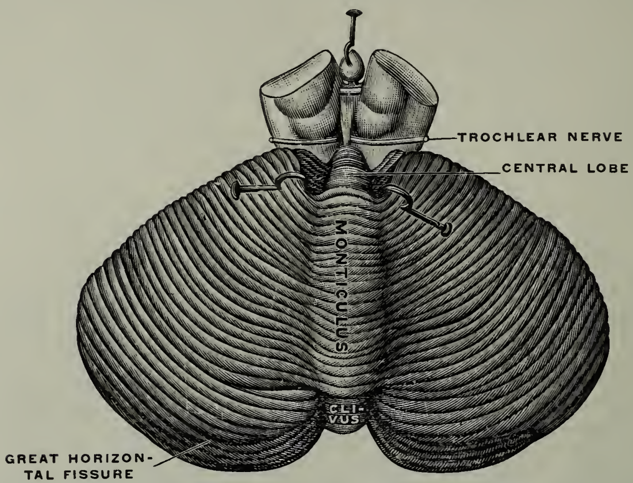


Fig. 204.—Upper surface of cerebellum. The lingula and cacumen are concealed by overhanging parts. The label "monticulus" is on the culmen. (Testut.)

sation of the pyramids." It is larger above, tapering below to about the same size as the upper region of the cord. (Fig. 206.)

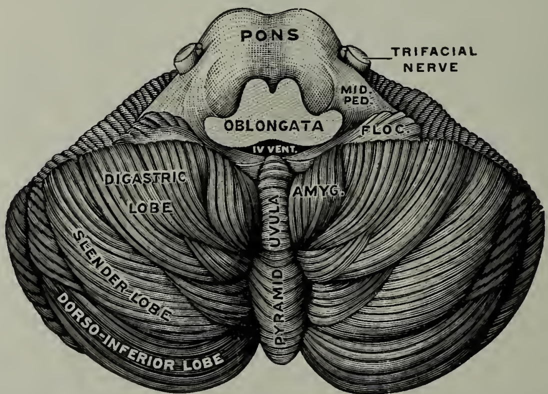


Fig. 205.—Under surface of cerebellum. The hemispheres are pulled apart to give a view of the inferior vermis. The nodule is between the uvula and the fourth ventricle. (Testut.)

As the other parts of the brain have been considered, it will be well to turn ahead to the section describing the spinal cord so as to note the relations of the medulla to both.

In comparing the medulla with the cord it should be noted that while in the brain the gray matter is mostly on the outside, in the cord it is in the center, shaped crudely like a letter "H." The white substance is separated by the legs of the "H" into three columns on each side, ventral, dorsal and lateral. These divisions, of both the gray and the white, are continued upward from the cord into the medulla, but their relations are changed. The gray matter is broken up into a number of separate parts, and there are a number of additional nuclei. The white fibers, some of which carry messages to the brain, some from it, seem to be continued

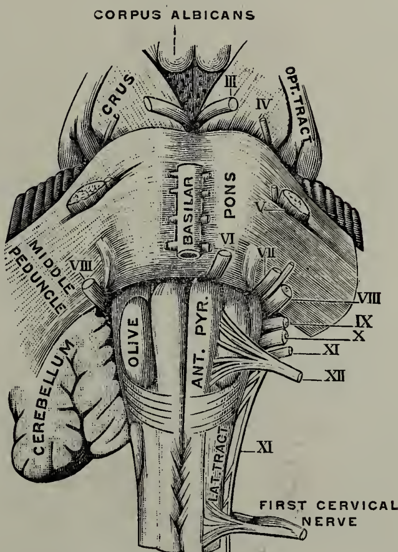


Fig. 206.—The pons and medulla, ventral view. (Testut.)

upward into the corresponding part of the medulla, but this is not always the case, and the bundles of fibers may be turned in new directions in a very complicated fashion.

The Decussation of the Pyramids.—On the ventral surface of the medulla is a longitudinal fissure, the *ventro-median fissure*, which is interrupted by a criss-cross of nerve bundles. On each side of the fissure is a white body which seems to be directly continuous with the ventral column of the cord. These are the *ventral* (anterior) *pyramids*, and the crossing over of the fissure at their lower part, so that the fibers on the right go to the left side, is called the "decussation of the pyramids." This is the arrangement through which the

left side of the brain controls the right side of the body, and *vice versa.* (Figs. 207, 208.)

From the medulla, come the cranial nerves from the sixth to the twelfth, inclusive, and the first spinal nerve.

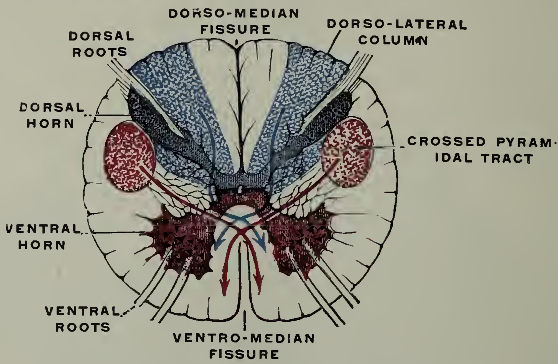


Fig. 207.—Transverse section of the medulla at its lower end. (Testut.)

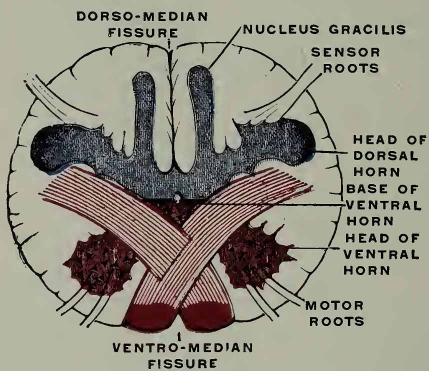


Fig. 208.—Transverse section of medulla at the decussation of the pyramids. (Testut, after Duval.)

ANATOMY OF THE SPINAL CORD WITH MOTOR AND SENSORY PATHS.

The *spinal cord* or *myelon* is the second part of the cerebrospinal axis and is the direct continuation of the medulla.

It extends from the foramen magnum, or from the "decussation of the pyramids" to the lower border of the first lumbar vertebra. It is about 18 inches long, on the average, and varies in diameter from $\frac{5}{8}$ to 1 inch. It terminates in a slender filament, called the "filum terminale" (Fig. 209). The cord does not occupy the full length of the spinal canal, but from the lumbar enlargement the

sacral and coccygeal nerves come off and hang down into the lower part of the canal in a formation to which is given the name, "cauda equina" or horse's tail from its resemblance to that object. There is considerable margin between the sides of the spinal canal and the cord, so the latter can move rather freely.

The cord has coverings similar to those of the brain, with corresponding uses. The *dura*, one layer serving as the periosteum of the canal, the other covering the cord, is on the outside, extending to the intervertebral foramina; the *pia*, a delicate mesh of blood-vessels close to the cord, and between the two the *arachnoid*, enclosing the arachnoid fluid. This fluid serves as a water-bed or cushion to protect the cord from external violence.

From the cord on each side are given off *spinal nerves* to supply the skeletal muscles of the body below the head, and transmit the sensory impressions from the same regions.

A cross-section of the cord (Fig. 210), shows it to be composed of gray and white substance. The gray is placed in the center, the white, outside. On the surface are a number of creases. In the middle line of the front is a deep and rather broad fissure, called the *ventral* or *ventro-median fissure.* In the middle line posteriorly is a less well marked cleft, the *dorsal* or *dorso-median fissure.* At each side of the dorsal fissure, about one-fourth of the distance toward the front is the slight *dorso-lateral fissure,* and between this and the dorsal is the *dorso-intermediate fissure.*

The nerves given off from the cord arise by two roots, the dorsal root which comes from the posterior horn of the gray matter, at the dorso-lateral fissure, and the ventral, coming from the ventral horn some distance to the outer side of the ventral fissure.

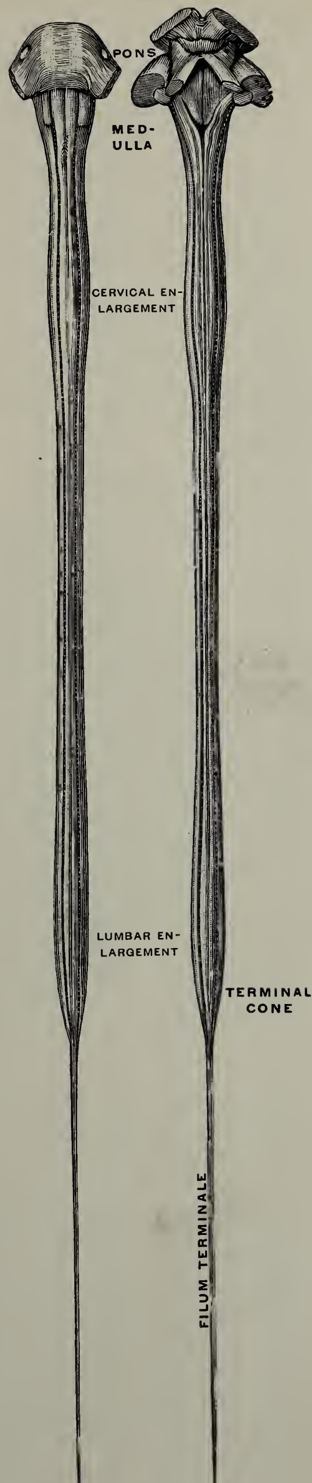


Fig. 209.—Spinal cord, medulla and pons. Left-hand figure is ventral view, right-hand is dorsal. (Testut.)

The White Matter of the Cord.—Between the ventral fissure and the ventral roots the white fibers form the anterior or ventral column. Between the ventral and dorsal roots is the lateral column, while between the dorsal roots and the dorsal fissure is the dorsal or posterior column, which is subdivided by the dorso-intermediate fissure into the dorso-lateral and the dorso-median columns. (Fig. 211.)

The white substance of the cord is formed of medullated fibers either going down the cord from the brain or upward to the brain. They form distinct tracts that have been traced, and their functions determined. These include the columns of Goll, Burdach and Clarke.

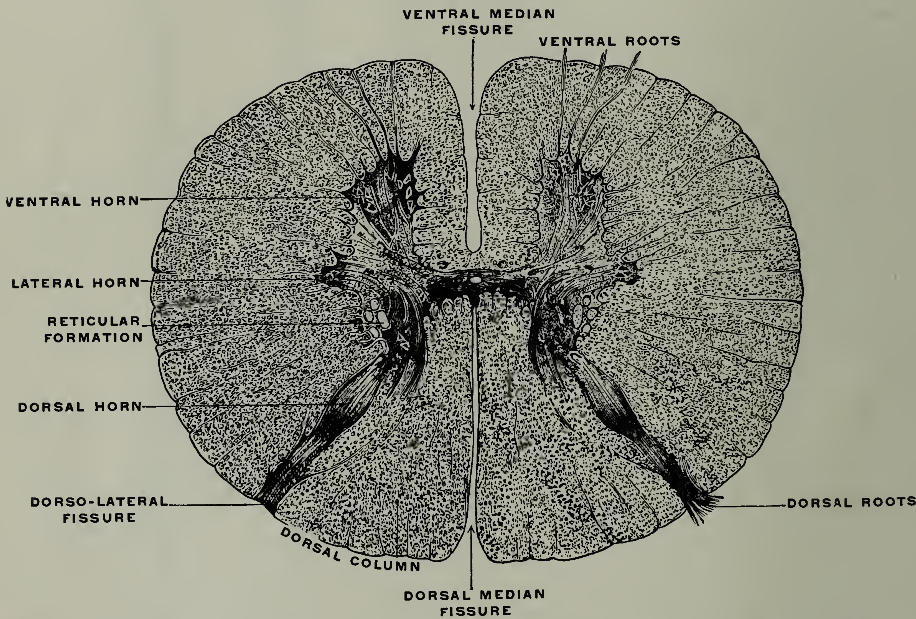


Fig. 210.—Transverse section of the spinal cord at the middle of the thoracic region. The neuroglia septum has been removed from between the dorsal columns. (Testut, after Pierret.)

A white commissure, placed in front of the anterior part of the gray commissure, connects the two sides of the white matter in the cord, as fibers pass from one side to the other.

The Gray Matter of the Cord.—The gray matter of the cord is arranged in the shape of a very crude letter "H," having the front horn or cornu much wider than that at the rear. From the posterior part of the ventral cornu the lateral cornu juts out, more pronounced in the upper dorsal region. The cross-bar or *gray commissure* has an aperture which indicates a small canal, continuous

throughout the cord, which is called the "central canal of the cord." It communicates with the fourth ventricle of the brain.

By reference to Fig. 231 it will be seen that the size of the cord and the proportion of gray matter varies at different levels. The cervical enlargement and the lumbar enlargement mark the giving off of spinal nerves to the upper and lower extremities respectively.

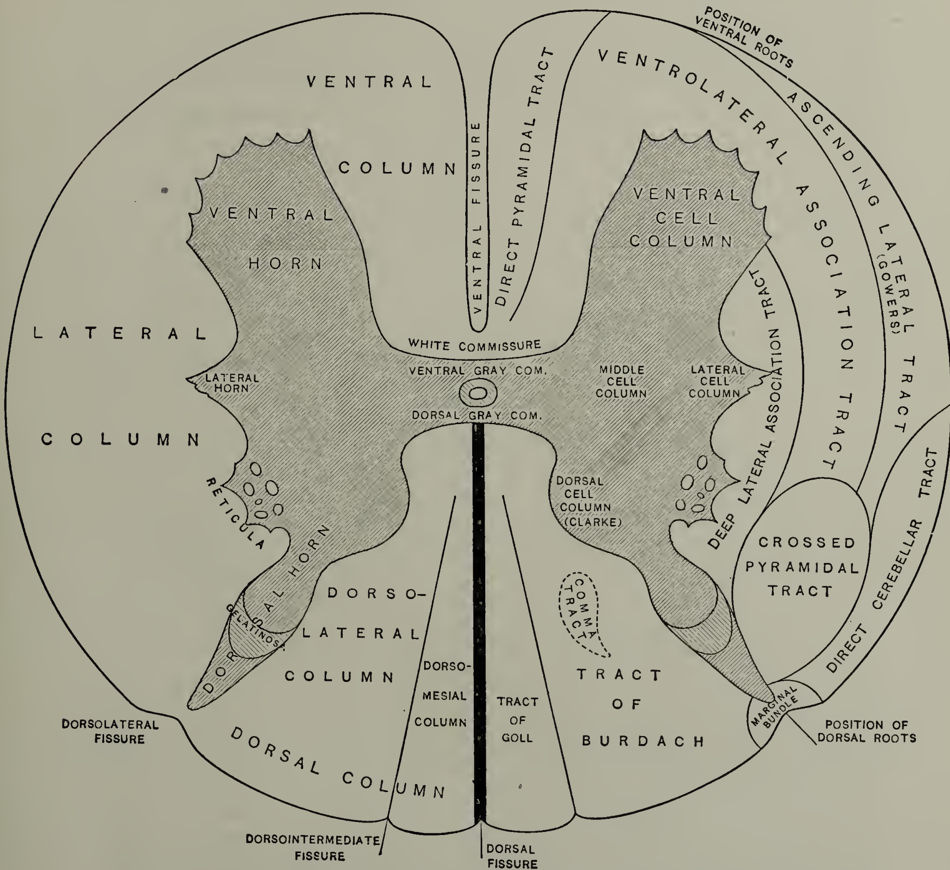


Fig. 211.—Diagrammatic ideal transverse section of the spinal cord. On the left side are shown the gross divisions; on the right side, the conduction paths. (Gerrish.)

This gray matter consists of neuroglia, enclosing and supporting a network of cells, fibers, medullated, and non-medullated, blood-vessels and lymphatics.

Ventral Horns.—The ventral horns of the gray matter of the cord contain large cells from which emerge large axones that go out as the ventral (anterior) or motor roots of spinal nerves, to energize the skeletal muscles.

Smaller cells are in the lateral horns in the thoracic region. These send out small axones which pass out at the ventral roots with the above, but go by way of a sympathetic ganglion and additional axones from the cells of the ganglion to the muscles in the walls of bloodvessels and hollow viscera, and to the epithelial cells of glands.

Dorsal Horns.—From the seventh cervical to the third lumbar the dorsal horns contain a group of cells known as "Clarke's column." Nerve fibers entering the spinal cord through the posterior roots, and carrying sensations from muscles, joints, skin and tendons, arborize around these cells. From the cells pass axones which go out into the white columns and ascend to centers in the cerebellum,

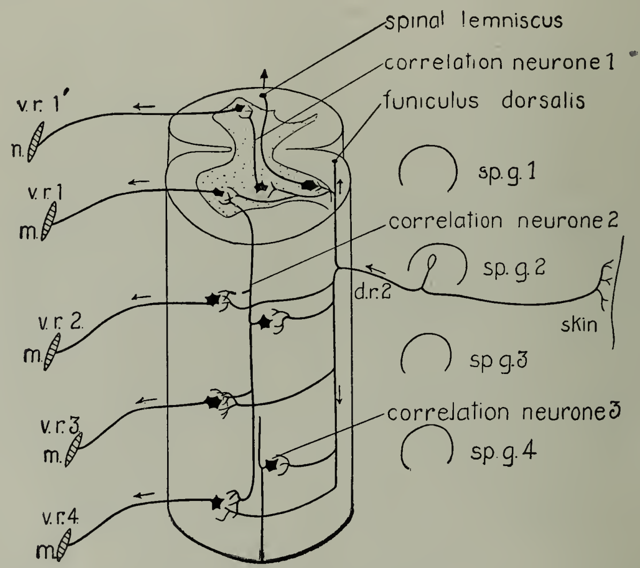


Fig. 212.—Diagram of the spinal cord reflex apparatus. Some of the connections of a single afferent neuron from the skin (*d.r.*2) are indicated: *d.r.*2, dorsal root from second spinal ganglion; *m*, muscles; *sp.g.*1 to *sp.g.*4, spinal ganglia; *v.r.*1' to *v.r.*4, ventral roots. (After Herrick.)

arborizing around the cells therein. From these cerebellar cells axones pass downward, which control the contraction of muscles concerned in maintaining the equilibrium of the body. (Fig. 211.)

A second group of cells receives sensations of pain, temperature, touch and pressure from cutaneous areas, and sensations from the viscera. Their axones pass to the other side of the spinal cord and go upward in the tract of fibers internal to Gower's tract and in front of the ventral horn, ending in the postcentral convolution of the cortex. (Fig. 211.)

A third group of cells receive sensory impressions from the muscles, joints and tendons. Their axones pass upward in the

columns of Goll and Burdach, through the medulla to areas in the cortex where they produce sensation as to the position of the various parts of the body, the direction of movements, the amount of resistance, etc. This is the "kinesthetic sense." (Fig. 211.)

Correlation Neurons.—Another group of cells in the dorsal horns is the so-called "correlation" neurons. Their axones branch, some going to communicate with the dendrites of cells (form synapses) in the ventral horns on the same level. Other branches pass upward or downward to cells on higher or lower levels. They are concerned in transferring or amplifying stimuli which arrive at or depart from the cells in the cord. (Fig. 212.)

The *gray commissure* of the cord is formed by unmedullated fibers passing from one side of the cord to the other side.

Cells in the cord are thus, either: afferent, receiving messages; efferent, sending messages; or those whose axones serve as connecting links between the other two kinds.

The cord is also divided into segments corresponding to the number of the vertebræ. Each of these segments, through the spinal nerves, has a definite relation with a definite region of the body. (Fig. 214.)

THE CEREBROSPINAL NERVES AND PLEXI.

Having considered the cranial and spinal centers, it remains to discuss the branches of each which carry the messages to and fro. Those from the brain are the cranial nerves, and those from the cord are spinal nerves.

All the spinal and some of the cranial nerves are mixed nerves, that is, they contain both motor and sensory fibers.

The spinal nerves arise by two roots from the cord. The anterior or ventral root is motor, several bundles of axones coming from the motor cells in the anterior horns of gray matter.

The posterior or dorsal root is sensory. It comes from the posterior horn of the cord. On this root is a group of cells called a ganglion. From the cells two processes arise, one going back to the cord, the other out to help form the spinal nerve. The two roots unite into one trunk that passes out through the intervertebral foramen. (Fig. 213.)

Just after leaving the spinal canal, a recurrent branch is sent back. It receives a branch from the sympathetic and goes into the spinal canal to supply the meninges and bloodvessels. The spinal nerves divide into anterior and posterior primary divisions, the posterior division later dividing into internal and external branches. The anterior division sends a branch, the ramus communicantes, to connect with the neighboring ganglia of the sympathetic.

The Spinal Nerves.—There are 31 pairs of spinal nerves, 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal. The first cervical nerve comes from the medulla, and passes out of the canal above the atlas. The eighth cervical passes between the seventh cervical and the first thoracic vertebræ. The first 7 cervical nerves are named from the vertebra below them, while the thoracic, lumbar and sacral nerves are named from the vertebra above them.

The dorsal primary divisions of the spinal nerves supply the skin on the back of the head, neck, trunk and gluteal regions, and the muscles that act directly upon the spinal column. These dorsal (primary division) nerves divide into internal and external branches, but they are smaller than those that are formed from the ventral division. The nerves of the ventral primary division are joined by rami communicantes from the neighboring sympathetic ganglia. By this arrangement the structures supplied by the sympathetics may be reflexly affected through stimulation of the spinal nerves (Fig. 213).

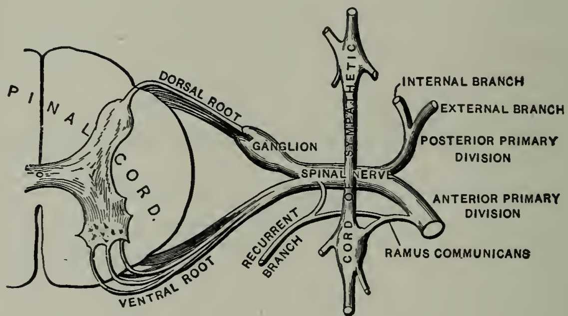


Fig. 213.—Plan of the constitution of a spinal nerve. (Keiller.)

In the thoracic region, the ventral division, as the intercostal nerves supplies the intercostal muscles.

Elsewhere, they form plexi, from which the nerves to the periphery start. (Fig. 215.)

There are four plexi, the cervical, the brachial, the lumbar, and the sacral.

The Cervical Plexus.—This is an intricate combination from the anterior divisions of the first four cervical nerves. With the exception of the first, each nerve divides into an upper and lower branch. The branches unite, forming three loops. (Fig. 216.) Some of the branches from the loops are superficial and some are deep. The parts supplied are the muscles about the head and neck, the trapezius, levator scapulæ, scalenus medius, and the sterno-mastoid. One long nerve, the phrenic, supplies the diaphragm. The nerve on the right side supplies the under surface while that on the left supplies the upper surface of that muscle.

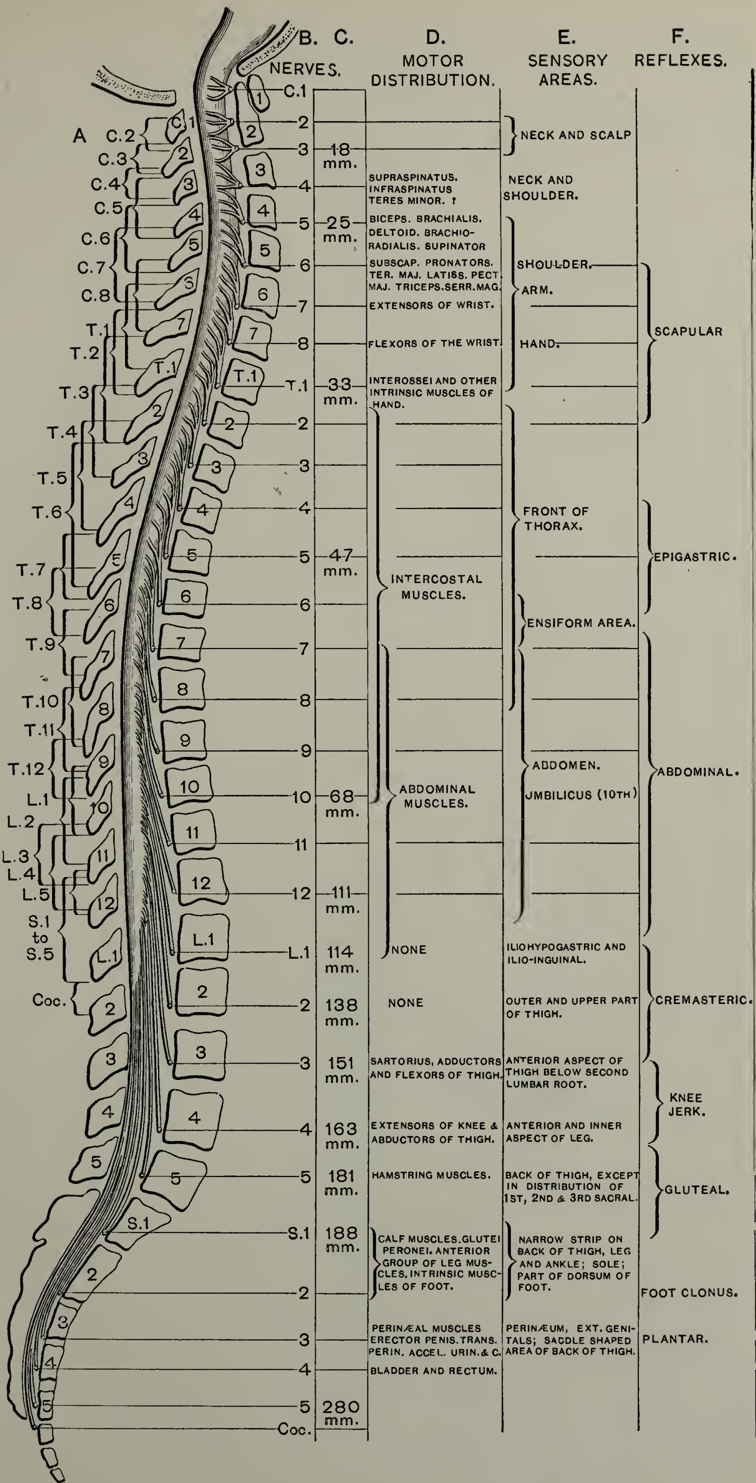


Fig. 214.—Topography and distribution of the spinal nerve roots. (Gerrish.)

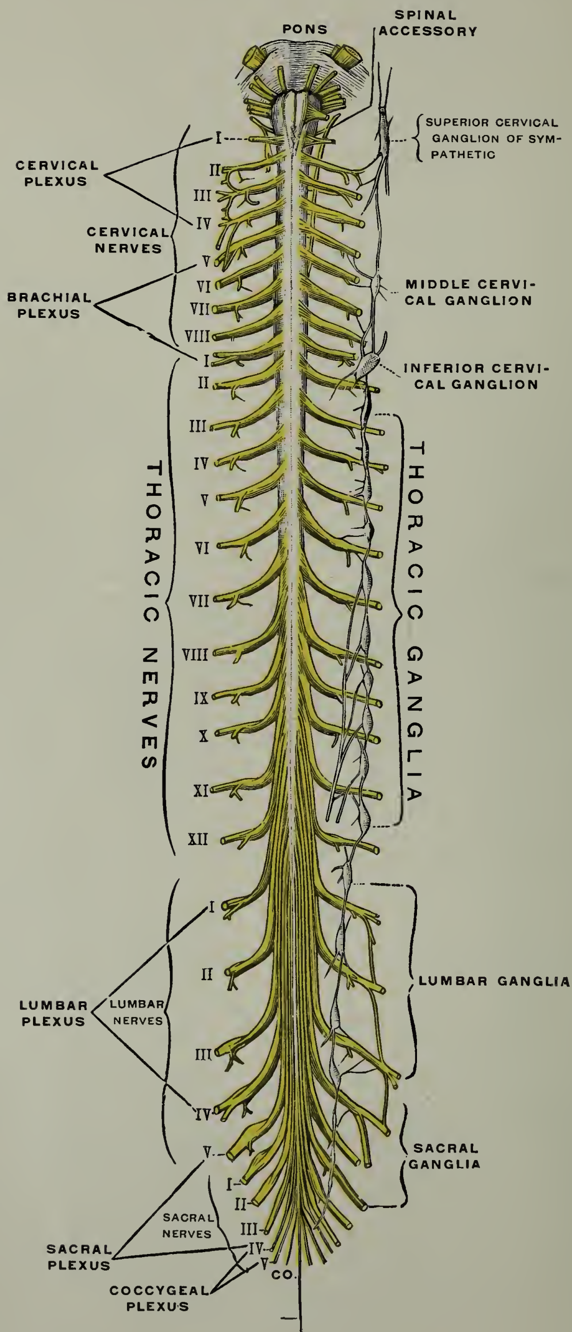


FIG. 215.—Anterior surface of the spinal cord, showing the spinal nerves and their connections with the sympathetic trunk on one side. (Testut.)

The Brachial Plexus.—This is formed from the fifth, sixth, seventh and eighth cervical, and the first thoracic nerves, with branches from the fourth cervical and the second thoracic. These nerves,

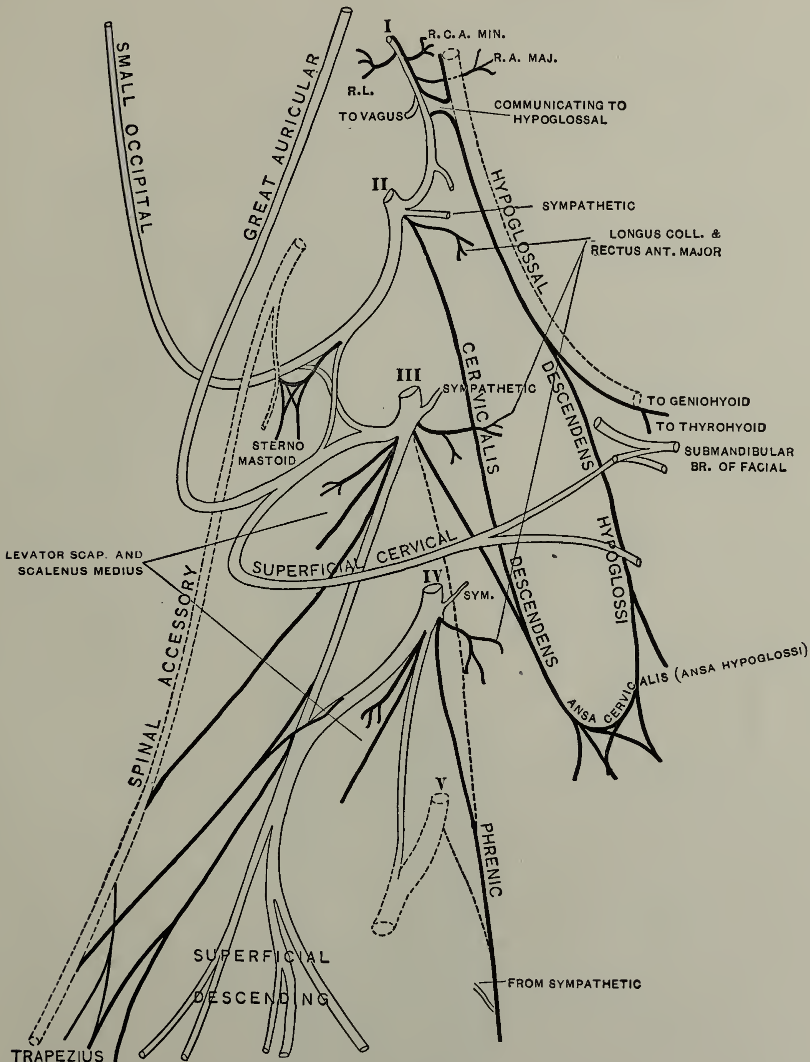


FIG. 216.—Plan of cervical plexus. (Gerrish.)

by their union before breaking up into terminal branches, provide fibers from most of the five segments for each terminal branch. This association is important in bringing about the orderly movements of the muscles of the upper extremity. Reference to the

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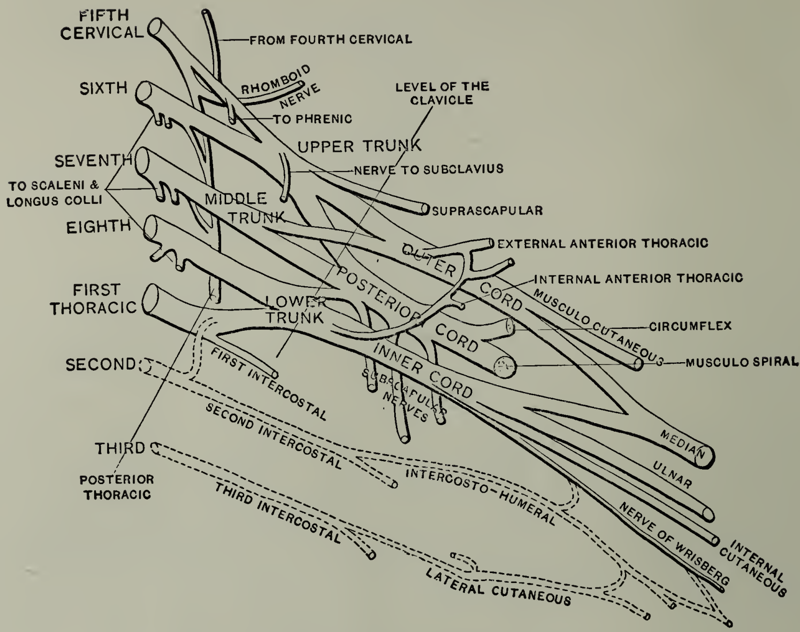

Fig. 217.—Plan of brachial plexus. (Gerrish.)

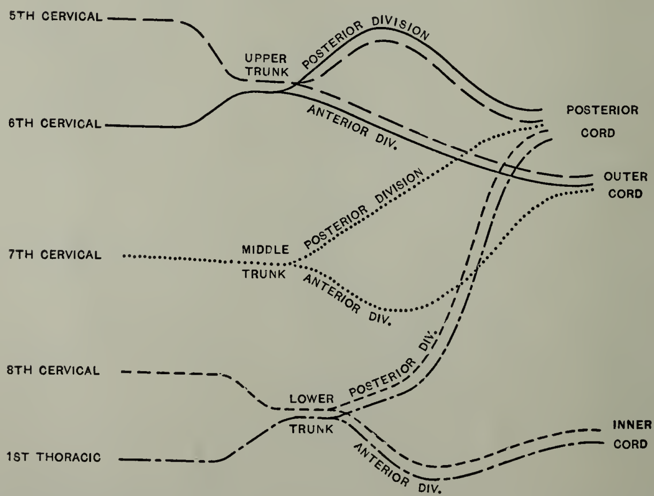

Fig. 218.—Diagram to show the component spinal nerves in the peripheral branches of the brachial plexus.

diagram (Fig. 218), will show the fifth and sixth cervical nerves uniting to form the upper trunk; the seventh cervical forming the middle trunk, and the eighth cervical and first thoracic forming the

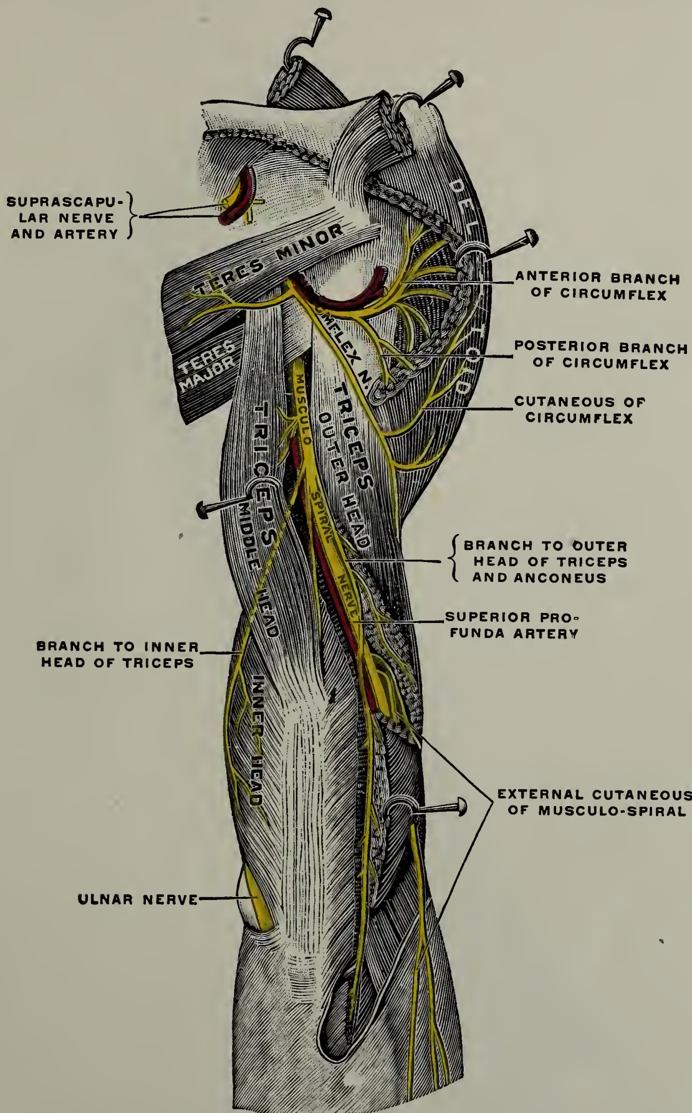

Fig. 219.—Musculo-spiral and circumflex nerves of right side. (Testut.)

lower trunk. Each trunk then divides into anterior and posterior branches. The anterior branches of the upper and middle trunks form the outer cord. The anterior division of the lower trunk forms

FIG. 220.—Cutaneous nerves of the upper limb, ventral aspect. (Keiller.)

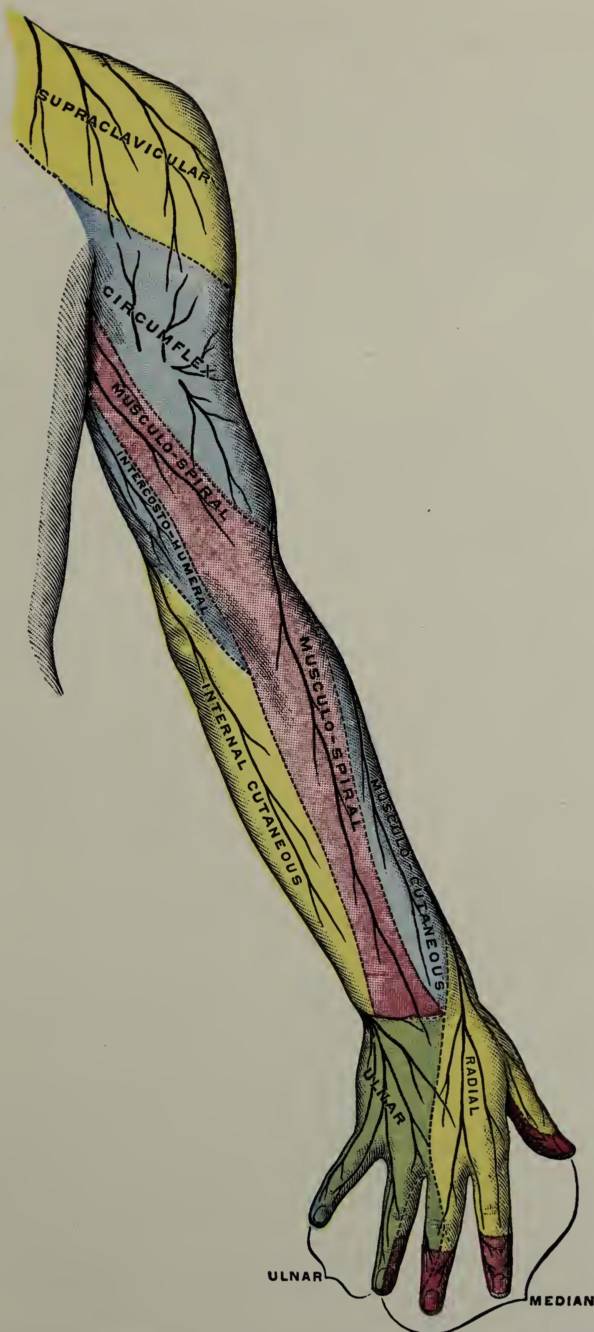

FIG. 221.—Cutaneous nerves of the upper limb, dorsal aspect. (Keiller.)

the inner cord, while the posterior divisions of all three trunks form the posterior cord. (Figs. 217 and 218.)

The outer cord divides into the *musculocutaneous* and the outer head of the *median;* the inner cord into the inner head of the *median,* the *ulnar,* the *internal cutaneous,* and the *lesser internal cutaneous;* the posterior cord into the *circumflex* and the *musculospiral.* Other nerves are given off to the rhomboidii and the subclavian muscles. The suprascapular nerve to the supraspinatus and the infraspinatus; the posterior thoracic nerve to the serratus magnus; the external and internal anterior thoracic nerve to the pectoralis major and minor muscles; and the long subscapular nerve to the latissimus dorsi muscles.

The *musculocutaneous* nerve supplies the coracobrachialis, the biceps, and the brachialis muscles. The *median* nerve passes down on the inner side of the arm between the biceps and triceps muscle, and then passes down the middle of the front of the forearm, supplying all the muscles on the front of the forearm (except the flexor carpi ulnaris and a part of the flexor profundus digitorum), and the short muscles of the thumb that are on the radial side of the flexor longus pollicis.

A deep branch of the median is the *anterior interosseous.* Branches are sent to the skin over the muscles supplied and to the joints those muscles move.

The *ulnar* nerve passes down the inner side of the arm, then between the internal condyle and the olecranon process, and into the forearm. It supplies the flexor carpi ulnaris and the half of the flexor profundus digitorum muscles. The whole of the little finger and the ulnar side of the next finger receive sensory fibers from the ulnar nerve. (Figs. 219 and 221.) It sends a branch to the elbow, and supplies the third and fourth lumbricales.

The *circumflex* nerve supplies the deltoideus muscle and the shoulder-joint.

The *musculospiral* or *radial* nerve descends diagonally across the back of the arm and at the elbow divides into the *radial* and *posterior interosseous.* It represents fibers from the five spinal nerves forming the brachial plexus. This nerve, with the two terminal branches supplies *all* the extensor muscles of the arm, forearm, and hand, from the triceps, brachio-radialis, extensors carpi radialis longus and brevis, extensor carpi ulnaris, extensor communis digitorum, to the special extensor of the index finger and of the thumb. It also supplies the joints moved by these extensor muscles, from the shoulder-joint to those of the phalanges. (Fig. 219.)

The distribution to the skin of the nerves of the brachial plexus is observed in Figs. 220 and 221.

The Thoracic Nerves.—The anterior divisions of the thoracic nerve do not form any plexi. Reference to the outline of the spinal

cord will show the thoracic portion as less in diameter than either the cervical or lumbar regions, as there are no large groups. The first eleven are between the ribs and named from the rib above. The last is below the twelfth rib.

Each nerve is connected with an adjoining sympathetic ganglion by rami communicantes.

The nerves supply the walls of the thorax and abdomen, the intercostal muscles, the subcostales, part of the obliquus externus abdominis, the serratus posterior superior, the rectus abdominis and the transversus.

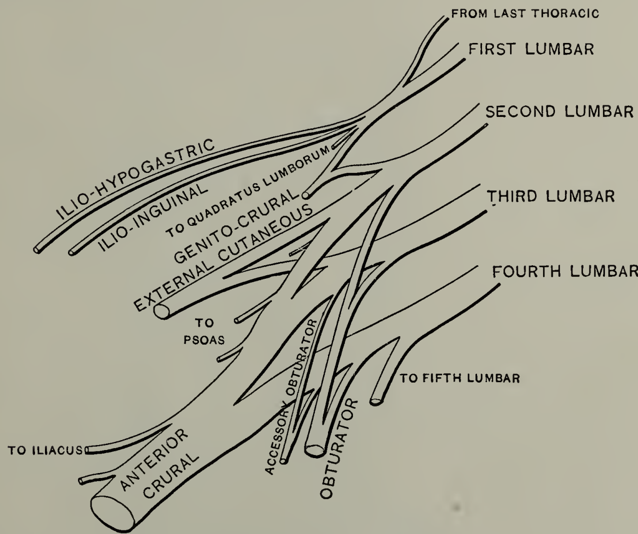

Fig. 222.—Plan of lumbar plexus. (Keiller.)

The Lumbar Plexus.—This is formed from the first, second and third lumbar nerves, with a part of the twelfth thoracic and the fourth lumbar. It is embedded in the psoas magnus muscle. (Fig. 222.) Branches from the plexus supply the muscles on the front and inner side of the thigh, the abdominal wall and the reproductive organs.

Among the principal branches are the *iliohypogastric* and the *ilioinguinal* which go to the abdominal wall muscles.

The *anterior crural* or *femoral* nerve supplies the iliacus, the pectineus, the rectus femoris, the vasti muscles and the sartorius. It passes out of the abdomen and accompanies the femoral artery and vein.

The *obturator* nerve supplies the adductor muscles, obturator internus and externus, besides the hip-joint, and the knee-joint.

It may be taken for granted that a nerve that supplies a muscle also sends a branch to the joint that muscle moves and to the skin over both. (Hilton.)

The Sacral Plexus.—This is formed by the part of the fourth lumbar, the fifth lumbar and the first four sacral with branches from the fifth sacral and the coccygeal. (Fig. 223.) The nerves of the plexus pass toward the greater sacro-sciatic foramen, and form a band from which several branches arise. The band continues as the *great sciatic* nerve which passes out of the pelvis external to the tuberosity of the ischium. It descends under the gluteus maximus and the biceps femoris, to the lower third of the thigh, where it divides into the internal popliteal (tibial) and the external popliteal (common peroneal). (Fig. 224.)

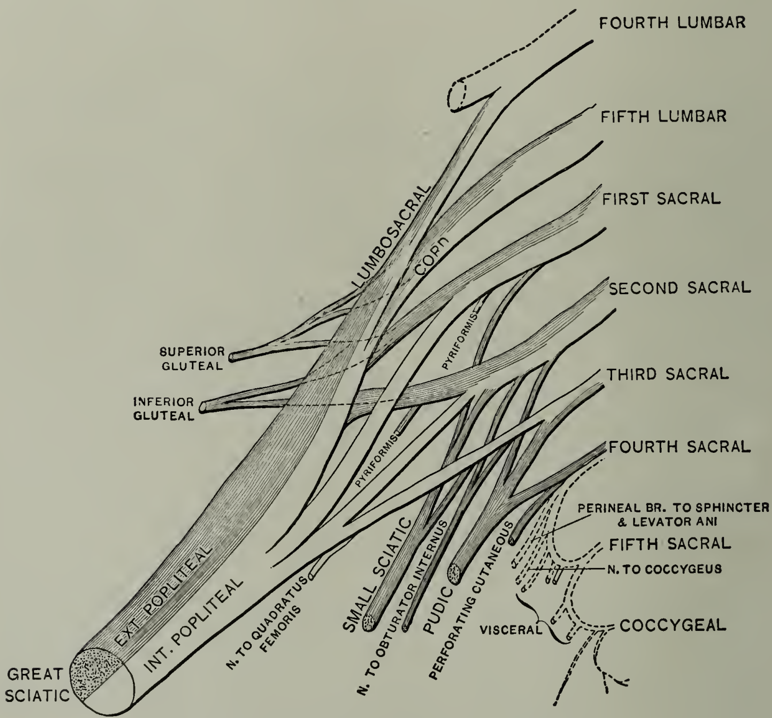

FIG. 223.—Plan of sacral plexus. (Gerrish.)

The Sciatic Nerve.—The sciatic nerve is the largest nerve in the body, having a cross-section of 1 cm. It supplies the greater part of the skin of the leg through cutaneous branches. By its articular branches it supplies the hip-joint, the knee-joint, and all the other joints of the lower extremity that are moved by the muscles innervated by this great nerve.

In the thigh branches supply the biceps femoris, adductor magnus, semitendinosis, and semimembranosus.

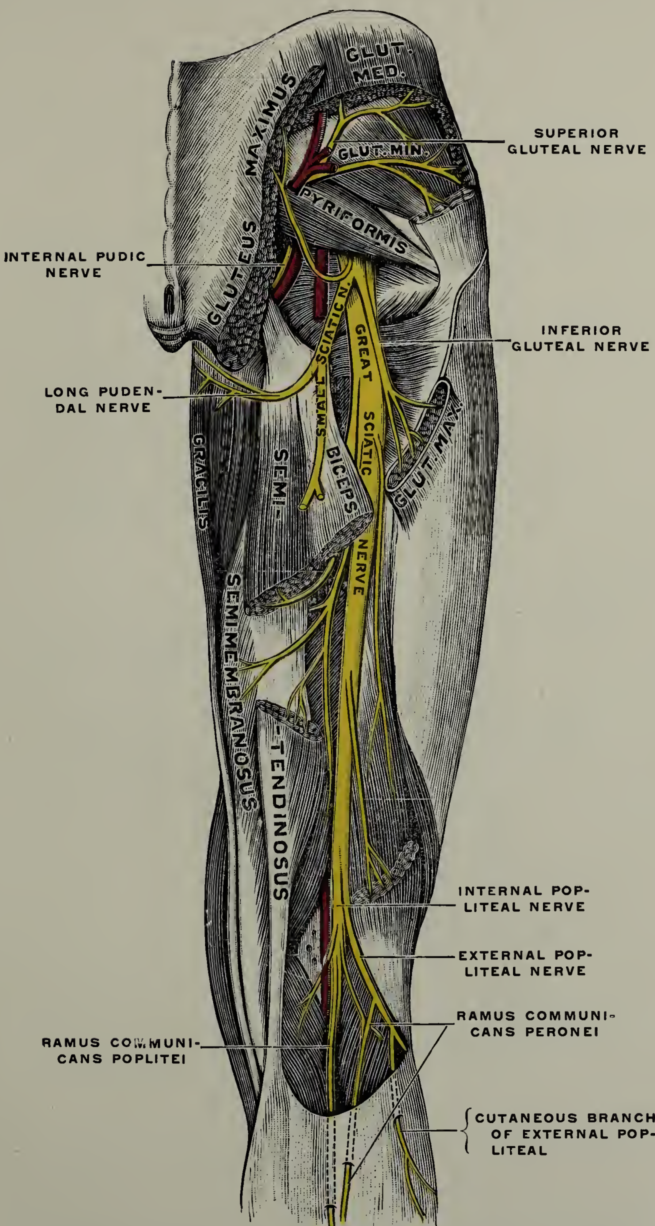

Fig. 224.—Deep nerves of buttocks and back of thigh. (Testut.)

The *tibial nerve* passes along the back of the lower thigh, through the popliteal space, down the back of the leg (Fig. 225), in company

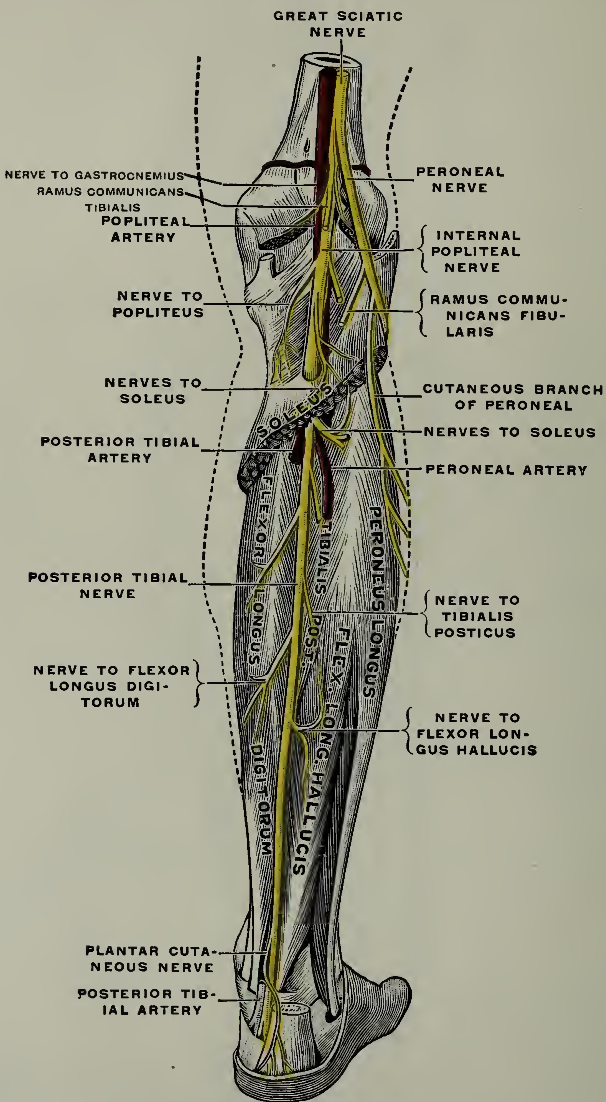

Fig. 225.—Deep nerves of the back of the leg. (Testut.)

with the posterior tibial artery to the space between the heel and the internal malleolus, where it divides into the internal and external plantar nerves. Branches from the tibial supply the gastroc-

nemius, plantaris, soleus, and popliteus, with the tibialis posterior, flexor digitorum longus, and flexor hallucis longus. The terminal plantar nerves supply the skin, joints and muscles of the foot.

The *common peroneal* nerve passes through the popliteal space, winds around the head of the fibula, and divides into the deep and superficial peroneal nerves. The deep branch goes inward, resting

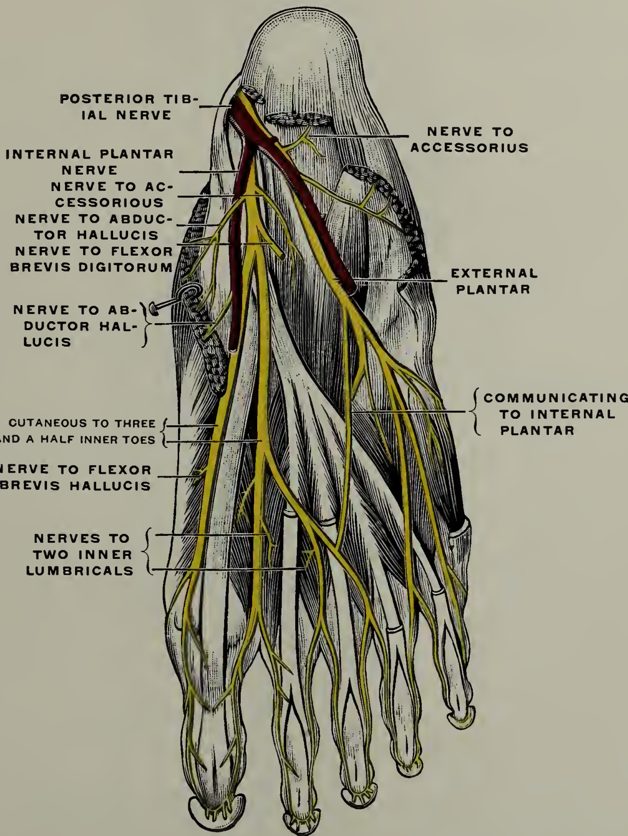

FIG. 226.—Plantar nerves. (Testut.)

on the interosseous membrane down to the front of the ankle-joint, where it divides into two terminal branches to the foot. (Figs. 227 and 228.)

The branches of the sciatic supply *all* the muscles of the leg, besides the flexor muscles of the thigh. The sciatic comes from the anterior division of the sacral plexus.

The nerves coming from the posterior division of the plexus (they

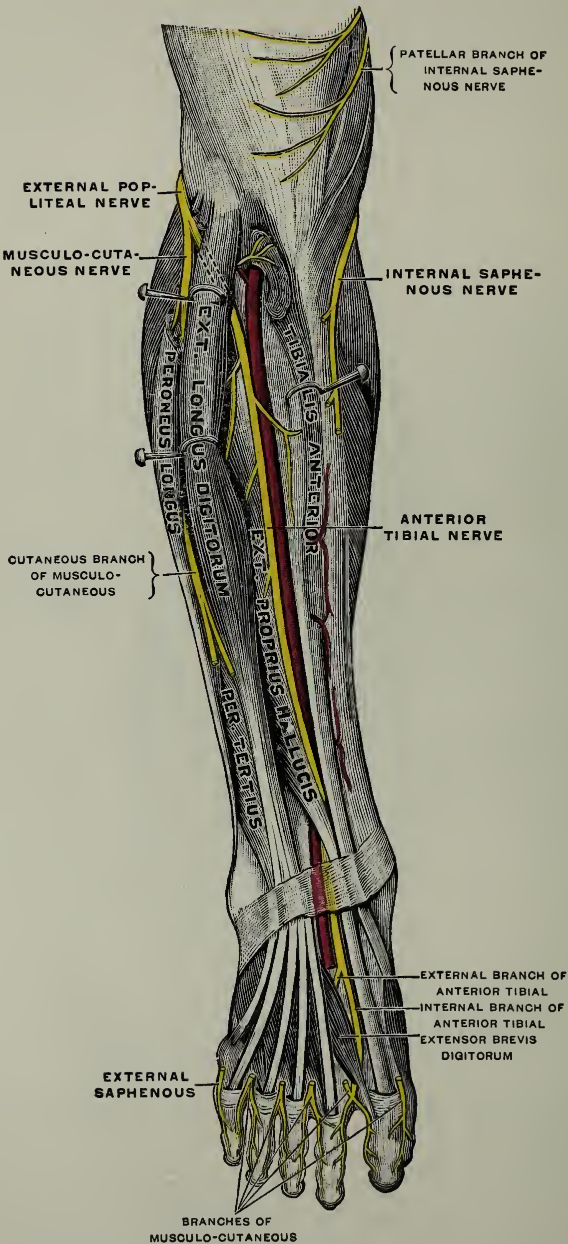

FIG. 227.—Deep nerves of the front of the leg. (Testut.)

are shaded in the diagram, Fig. 223) supply muscles on the back of the thigh—the gluteus magnus, medius, minimus, pyriformis, obturator internus, quadratus femoris, and the skin over them.

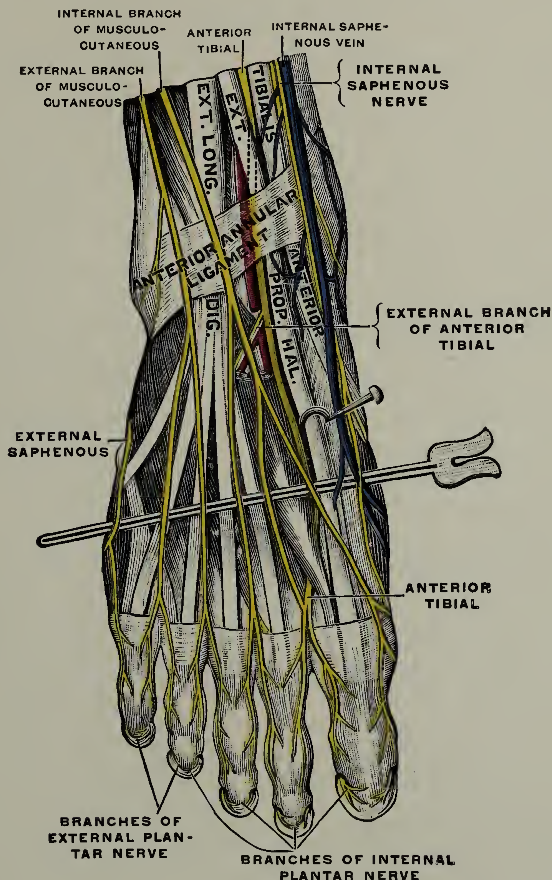

FIG. 228.—Nerves of the dorsum of the foot. (Testut.)

THE PHYSIOLOGY OF THE CEREBROSPINAL NERVOUS SYSTEM.

Functions of the Cerebrum.—For many centuries it has been recognized that the cerebrum is the seat of conscious sensation and intelligence. It has been known that the development of the brain was connected with, and dependent upon, the development of the cortical area of the cerebrum.

In tracing the development of the cerebrum, its starting-point seems to be the olfactory center. In the lower animals this is the sense which has most to do with their survival. It informs them of

danger, of the location of food, its suitability, and of their friends. In short, it carries news of the environment, to which the animal makes an appropriate response. In man the other senses that inform him of his environment have made the olfactory sense less important, so it is not highly developed. Afferent impulses pass to the cerebrum from which the necessary efferent stimuli emerge.

As previously stated life has been described as the continuous adjustment to one's environment. In this sense our continued existence is dependent upon the coöperation of all parts of the organism for the defense of every part. Any defect in the various parts of the nervous system destroys its harmonious operation. Loss of memory, motion, smell, taste, speech, etc., may result from defect or injury. If the bones of the skull unite too early, the cerebrum fails to develop. This results in stunted mentality.

The Cortex of the Cerebrum.—The cortex, in which the centers for thought, motion, will, and consciousness are located, is a great, central receiving station for information from outside the brain. It is the central station for determining and initiating the necessary responses to such information. It is the central station from which start the motor impulses that will result in appropriate action, whether voluntary or involuntary.

The cortex of the cerebrum contains a variety of nerve cells, arranged in some eight layers. Some of these cells are supposed to have only the work of connecting one part of the cortex with another part. Some cells shaped like a pyramid are called "pyramidal". These cells are typical of the cortex. They are cone-shaped, having at the apex a dendrite which breaks up into many branches. Dendrites come off from other parts of the cell. The pyramidal cell axones pass downward, becoming medullated, and sending off more branches. Branches and dendrites are to establish communication with other cells, pyramidal, or otherwise. The axones pass by the *corona radiata,* through the *internal capsule* into the *crura cerebri.* Many of these cells send their axones to the medulla. The pyramidal cells of the motor areas of the cortex give rise to the outgoing messages which proceed along their axones to the motor nuclei of the cranial or spinal nerves. From the cells of these nuclei, other axones carry the messages to the muscles or other parts that are to be stimulated. There may be intermediate stations where the impulse is accentuated or augmented, as the axones pass through the cerebellum or medulla, but there must always be these two stations, *i. e.,* the pyramidal cells and the motor nuclei of the cranial or spinal nerves. Some axones from the brain cross from one side to the other at the "decussation of the pyramids," going down to the spinal neuron on the opposite side to that in which the impulse originated.

Areas of the Brain—Motor and Sensory.—The cortex is a vast aggregation of neurons. Some of the cells receive messages by afferent or sensory axones, some cells send out messages by efferent or motor axones. Some neurons are *intermediaries.*

Apparently, every sense organ, the eye, the ear, the nose, the tongue and the skin, has its own place where messages are received.

The areas for voluntary movement are in the frontal lobe; for skin sensation, in the parietal; for hearing, in the temporal; for taste and smell, in the limbic; and for vision, in the occipital or calcarine lobes. The higher, psychic centers are assigned to the frontal lobe. Muscle and visceral sensations likewise have their areas, all somewhat posterior to the Rolandic fissure.

The motor areas from which voluntary muscles are stimulated are mostly grouped about the Rolandic fissure, somewhat to the front of it, and comprise those for the head and eyes, the face, the arm, the trunk muscles, and the leg. These areas follow the order in which the cranial and spinal nerves emerge from the brain and cord, those going to the head being at the lowest level.

The *center for speech,* located in Broca's convolution in the posterior part of the frontal lobe, has been thought to exist on the left side only. Persons with right-sided paralysis, due to lesions on the left side of the brain, are generally unable to speak, but if the paralysis is on the left side, showing involvement of the right side of the brain, the power of speech is generally present. As nearly all the brain functions are bilateral, it is thought there may be an undeveloped speech center on the right side of the brain that may be made to function by the development, through motor education of areas on the right side.

At present Broca's convolution is considered not a center, but an association area, connecting and harmonizing psychic, afferent impulses with motor impulses to the lungs, tongue, and vocal cords. Air from the lungs passes out through the larynx, setting the vocal cords into vibration. The muscles of the mouth vary the diameter of the column of air, producing variations of sound. By the action of the tongue, teeth, resonating chambers of the nose, mouth, and pharynx the voice is changed in resonance. The association fibers coördinate the action of the lungs in respiration through the phrenic and intercostal nerves. The principal cranial nerves involved by control of the larynx, tongue, lips, etc., are the seventh, tenth, and twelfth.

In voice production the pitch depends upon the length of the vocal cords; the strength or loudness upon the volume and force of the air passing through the larynx; the resonance or timbre upon the resonating chambers.

These various sensory and motor centers, however extensive, are of no use without the mediation of *association neurons,* which

pass between the sensory and psychic neurons, and the psychic and motor neurons. (Fig. 229.) It is said there is about the same absolute amount of cortex controlling motion and sensation in man and the dog or ape. But, relatively, the extent of these areas in man is dwarfed by the much greater cortical areas connected with *associations* which are involved in reflection and intelligence. Everything that is learned through experience, conditioned reflexes or new modes of response to afferent impulses, are centered in the cerebral cortex, through the association neurons. It is thought that more than one-half of the cortex is occupied by the association neurons. Through the interrelations thus established, and the

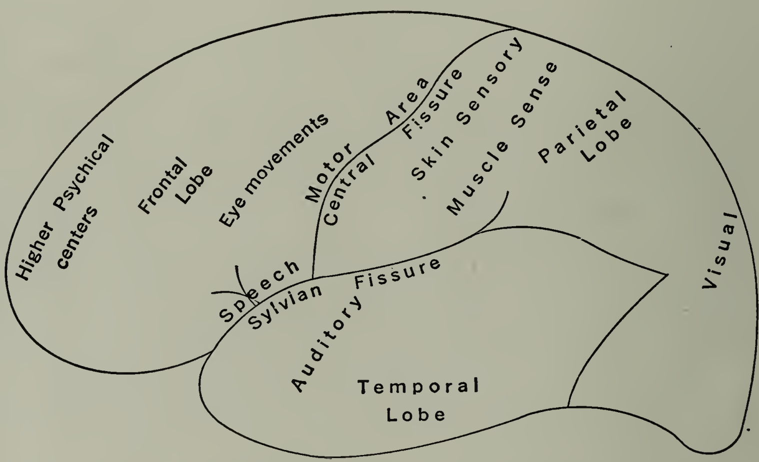

FIG. 229.—Some of the areas in the cerebrum.

working of the higher psychic centers, volitional impulses are evolved, and the most complicated processes occur. Writing, for instance involves memory of signs representing ideas, their arrangement, so they will be understood by others, and the painfully acquired motor skill in forming letters by the hand and arm.

These are all functions of the cortex of the cerebrum, largely developed through motor activity. *No* motor activity means *no* cortical development.

Reflexes.—Messages are carried to the brain by "afferent" nerves, while the "efferent" nerves carry a message from the brain to the periphery. Both are concerned in most actions, as the messages coming from the outside to the brain provoke some response, that is, some reflex, either of the voluntary or involuntary sphere.

As an instance, a bright light thrown into the eye causes the reflex of contraction of the pupil. A touch on the eyeball, causes the reflex of winking. The smell of appetizing food starts the secre-

tion of saliva. Such reflexes are impossible to control or prevent, and are spoken of as *unconditioned reflexes.*

Another kind of reflex, called *conditioned reflexes* may be obtained under certain conditions, or may be brought out by training or education. They are subject to various forms of inhibition, both internal and external. The method of obtaining them is as follows: if a certain sensory stimulation is given, as a note of a definite number of vibrations per second, there is no effect upon the secretion of saliva, but, if at the same time, the salivary glands are stimulated by acid, after a while the reflex of salivary flow comes from the note alone without the acid.

Many reflexes occur through the mediation of the cerebral cortex, and many others through the spinal cord. Those of the spinal cord however, may be inhibited by the brain. The involuntary jump that occurs upon hearing a sudden loud noise may be inhibited by the higher centers in the brain, so that in time, the individual makes few involuntary movements, or noticeable reflex actions.

The simplest reflex requires a certain number of elements. There must be an irritation at some peripheral point; an afferent or sensory nerve to convey this impression to the sensory cells in either the brain or spinal cord; an association neuron to carry this impression to the dendrites of an efferent or motor neuron, and an axone from the motor cell to a skeletal muscle. This arrangement provides for a very simple reflex, and elicits a single muscular contraction.

Strong peripheral irritations have the same mechanism plus some intermediate elements. The impression from the sensory cell may go by its dendrites to the dendrites of an association neuron in the brain, or of a correlation neuron in the spinal cord, to the efferent or motor neurons in many segments of the cord, initiating a reflex muscular action out of all proportion to the original irritation. It is possible for any sensory nerve to excite *all* the motor neurons in the spinal cord, by reason of the extensive synapses. It does not ordinarily so happen, as there is a resistance encountered. A person, tickled in the ribs, may go into a spasm of muscular contraction that is very extensive, but not necessarily coördinated. A "conditioned" reflex may be obtained from sensitive subjects by merely pointing the finger at their ribs.

Or, the irritation may go so far up the cord it reaches the medulla, with a resulting reflex both extensive and coördinated. These responses are made through the skeletal muscles which ordinarily respond to volitional stimuli, alone.

The various functions of the body, as the movements of respiration, the inhibition or excitation of the heart action, the variation in the caliber of the bloodvessels, the excitation or inhibition of the contraction of the muscles of the digestive tract, and the stimulation to secretion of the epithelial cells of glands, are all instances of reflex action.

In respiration, the presence of a certain amount of CO_2 in the blood irritates certain cells in the medulla, from which impulses go to the motor cells in the "inspiratory center." Thence are emitted the messages to the various muscles concerned in the inspiratory movements of the thorax and the harmonizing of their action.

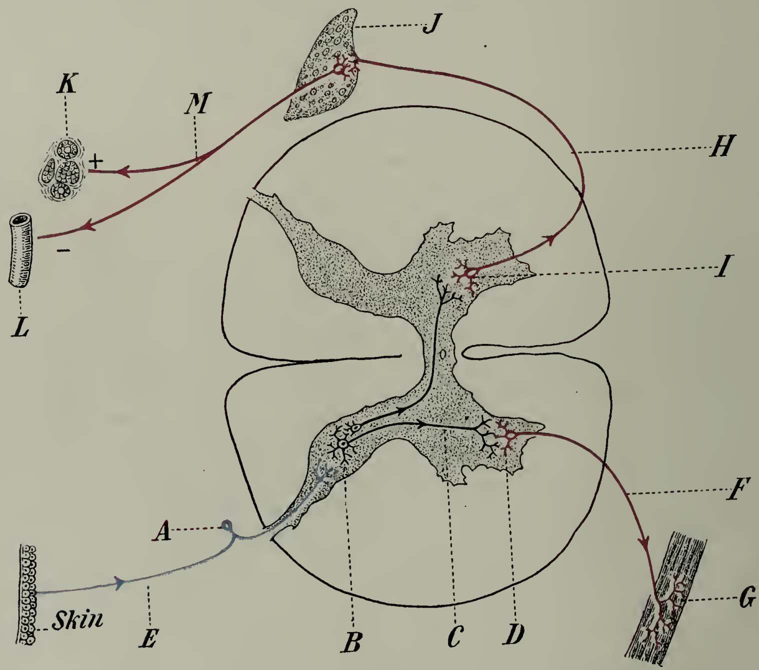

FIG. 230.—Diagram to illustrate reflex action. *A*, ganglion on sensory nerve root; *B*, cell of correlation neuron; *C*, axone of same; *D*, motor cell; *E*, sensory nerve from skin; *F*, motor nerve to muscle; *G*, muscle; *H*, preganglionic fiber, from cell I in lateral horn; *J*, sympathetic ganglion, with neuron outlined; *M*, postganglionic fiber from cell in *J*; *K*, sweat gland stimulated to activity (+); *L*, arteriole, whose circular fibers are inhibited (−).

Sensation from the skin may eventuate in a movement of the voluntary muscles, with a correlation neuron carrying on a message. Or a sensation from the skin may eventuate in the formation of sweat, and increased blood supply to skin, with a correlation neuron as intermediary.

The lower part of the diagram illustrates a reflex action in the cerebrospinal sphere. The upper portion shows the pathways in the autonomic sphere.

The activity of the sweat glands is a fairly complex reflex. An external temperature of over 70° F. will serve as an irritant to the sensory nerves of the skin. The message of this irritation is carried by the fibers to the cells in the posterior horns of the gray matter of the cord. Then, by correlation neurons to the vasomotor and sweat centers in the medulla. Efferent impulses pass down to the cells in the lateral horns of the gray matter, at various levels, outward in

the motor roots of the spinal nerves of a greater or lesser number of segments of the cord to the cells of nearby ganglia of the sympathetic. Axones from these ganglionic cells go to the walls of the cutaneous bloodvessels, inhibiting their contraction, so that they dilate, increasing the blood in the skin, and to the epithelial cells of the sweat glands, stimulating them to secrete. By this secretion of sweat, the temperature of the body is lowered, so helping to maintain the normal temperature of 98.6° F. even in high external temperatures. (Fig. 230.)

The Blood Supply of the Brain.—The brain is supplied with blood from the arteries that form the "circle of Willis" or arise from it. These are branches from the internal carotid, united to branches from the basilar and vertebral arteries. (Fig. 248.) This extensive anastomosis provides an abundant supply at all times, even if the internal carotid or the vertebral artery is shut off.

The veins which drain the brain are called *sinuses.* These are foldings of the *dura mater,* which, with grooves in the cranial bones form large, firm canals, which are capable of withstanding considerable pressure. (Fig. 195.) Several of these sinuses unite at the *torcular Herophili,* from whence the blood is carried through the lateral sinuses to the *internal jugular vein,* to the *brachiocephalic vein* and to the *superior vena cava.* (See the section on the Circulatory System for these arteries and veins.)

The Circulation in the Brain.—This is different from that in other organs in that the brain is enclosed in a rigid bony case that limits expansion. As the blood is sent out from the heart, the aorta and other large vessels expand. In the thorax the surroundings are soft enough to allow such increase in size. In the cranium the rigid walls limit it. Unless provision was made for the swelling great damage would be done to the brain. During systole the wave of blood coming into the cerebral arteries increases the size of the brain. This is met by a displacement of the *arachnoid fluid* into spaces outside the cranial cavity. A part of the increase is cared for in this way. The pressure of the brain upon the veins of the *pia mater* lessens their caliber, and so the rate of flow through them increases.

This carries the blood off more rapidly—enough to compensate for the arterial expansion. It also develops a *pulse* in the jugular vein, as the arterial pulse is transmitted through virtually rigid tubes.

The familiar feeling of "fulness" in the head, when taking exercises sufficiently strenuous to increase the heart rate, and, at the same time, holding the breath in expiration, is explained by this arrangement of the cranial circulation. The venous return flow to the heart depends largely upon the inspiratory movements. When these are checked the flow into the vena cava is blocked, and also the flow further back.

The effects of inspiratory movements in drawing blood from the brain is noticed in the sensation of "light-headedness" which follows a moderate number of deep breaths. In feeble persons it produces an absolute dizziness and faintness.

As no vasomotor nerves have been found in the cerebral arteries, the amount of blood going to the brain must be regulated in some other than the way usual with other organs. It is supposed that the general vasomotor control acts indirectly. If the circular fibers in the arteries are inhibited, the vessels dilate. In the skin and viscera this would increase their blood supply, while lessening that to the brain. It is thought that the brain is prevented from having too much blood, by the general vasomotor control dilating the arteries elsewhere, especially in the splanchnic area, so that the supply to the brain is diminished. If digestion is going on very little mental work can be done, and *vice versa.* If the blood is kept out of the skin and viscera more is available for the demands of the brain.

Cerebral Work.—During waking hours there is always more or less activity of the brain. Impressions from the outside world are continually arriving, eventuating in thought or action through the mediation of the associated neurons, the intellectual or motor centers. This implies a normal irritability of the various neurons, whose activity causes metabolic changes—the development of waste materials and the need of repairs. As work goes on the irritability lessens and the brain becomes fatigued. Other parts of the body, by the cessation of activity, may rest, but, as stated above, the brain is always more or less active, and so gets no rest until sleep intervenes.

Sleep.—During sleep there is much less blood sent to the brain. The heart beats less frequently and with less force. The respiratory rate is diminished. More blood is sent to the skin and viscera. Less irritability of the organs of sense, the eyes and the ears, is present, as also of the sense of touch.

For the first two or three hours sleep is more profound, so that ordinary noises and lights make no impression upon the consciousness.

Presently, the brain having been refreshed by the removal of waste products and the coming of new materials awakens, and the normal irritability of the neurons returns.

Apparently, the fundamental condition for sleep is anemia of the brain, by the transfer of blood to the periphery. Hence, the familiar observation that warming the feet will help to induce sleep. Also, when there is insufficient covering, by the chilling of the surface, the excess of blood in the skin is driven back to the interior, and hence to the brain. This condition effectually prevents sleep.

Following sleep or prolonged recumbency in the aged or weak,

a sudden change to the upright position is often accompanied by dizziness, more or less extreme. This is due to the inability of the circulation to adjust quickly enough. There is an excess of blood in the splanchnic area which cannot get to the heart and be sent to the brain in time to supply the increased need for the upright position. Persons should get up slowly with the head hanging relaxed, to prevent this possibility.

Functions of the Cerebellum.—It is supposed that the cerebellum coördinates muscular movements—especially those concerned in equilibrium and locomotion. This coördination appears to be largely reflex. The principal elements involved are sensory impulses from the skin, muscles, eyes, and the *semicircular canals* of the ear, together with motor impulses of various neurons in the cerebellum and the general muscles of the body. It may be an augmenting apparatus for voluntary movements. There is a lack of agreement among physiologists in regard to the work done by the cerebellum. Its loss seems to affect the muscular sense, and those of position and direction. Each half is connected with the corresponding half of the body.

The movements of the body that have a definite meaning must be learned by careful, painstaking repetition. Each time the movement is performed, it is easier, as the pathways through the association fibers offer less resistance. Finally, the details of the execution of this movement passes out of conscious control. The cerebellum takes over the supervision of the acquired habit. We see this in the child learning to walk. Note that expression, *he learns* to walk. In this process he goes through a number of preliminary, preparatory exercises, evidently *willed,* but of whose significance adults are not always cognizant. Presently, the child stands alone—then he walks, not as an accident, but through many trials. His walking is not steady, but after a time he need pay no attention to its mechanism. His attention is diverted from the way he must act in order to get somewhere else, to the thing he wants when he is there. The cerebellum has taken charge of his equilibrium and locomotion. It is not worth while for the cerebrum to give orders for the detailed execution of movements that are habitual, as the cerebellum can and does supervise such acts.

Cerebellar control is over *groups* of muscles, working to some definite end.

Kinesthetic Sense.—Kinesthetic sense, or proprioceptive sensations, refer to the consciousness of posture, either of the whole body or of any of its parts. The coöperation of sensory and motor impulses are necessary in the production of coördinated movements. When motor centers send orders out for the execution of certain movements, the sensory nerves must send back word as to whether

the contraction of the muscles is adequate and suitable. This gives a knowledge of position of parts, amount of resistance, or weight, that might be called a sense of posture. Without seeing, we appreciate in this way the position of any of our members.

The end organs of the kinesthetic sense are found in muscles, tendons, bone, cartilage, etc. Some are Pacinian corpuscles, some are nerve filaments wound around muscle fibers, and some are branched nerve endings. Impulses from these travel upward in the cord, in company with motor impulses, to the medulla, then on to the cortex. Other fibers, not sensory, going to the cerebellum, enables that part of the brain to correlate the action of groups of muscles.

All voluntary movements are dependent upon the kinesthetic sense for their orderly performance. The more complicated the movement, the more necessary it is that the sensory messages be coördinated with the motor responses. This is true of the slight contractions that are involved in the maintenance of the erect posture, and in the resumption of it after temporarily having it changed.

In considering posture in general, the position of the head has an important place. Normally, the eyes should be on a horizontal line, which is in the horizontal plane with the external occipital protuberance. To appreciate when one has this position requires information from the eyes, the semicircular canals, and the kinesthetic messages from the neck muscles.

The head almost balances itself, so that very little muscular effort is necessary to maintain its normal position. The kinesthetic messages from the neck muscles help in the appreciation of this position.

So far as equilibrium is concerned, the position of the trunk as related to the head becomes important. With the head in the middle line, it may be easy to walk a chalk line. Carrying a heavy basket on one arm compels the body to bend to the opposite side, with the head tilted toward the center. Under these circumstances, walking the "chalk line" becomes very difficult. Equal difficulty is experienced in walking if the sensory impressions from the sole of the foot are absent. If one's foot goes "asleep," the floor cannot be felt as resistance. Lacking this kinesthetic sensation, the vision enables one to stand if the muscles are not numbed.

In quadrupeds, if the animal is blindfolded, has the semicircular canals destroyed, and the neck fixed immovably, it will still be able to get up and stand when it is laid on its side. This it can do. through the sensory impressions from the surface on which it rested.

It is evident, then, that the kinesthetic sense, derived from the neck muscles, and the feet, together with vision, and the semicir-

cular canals are all concerned in problems of equilibrium and locomotion.

Functions of the Medulla.—A number of "centers" are located in the medulla and pons, which through an intricate coördinating mechanism of cells and fibers control a number of so-called "automatic" functions. The nuclei, or relay stations, for many of the cranial nerves are in the medulla. Many long path axones with their accessory structures pass through the medulla on their way between the spinal cord and the pyramidal cells of the cerebral cortex. Some of the special centers are:

1. A vasomotor center for the whole body, controlling the amount of blood going to areas according to the need of the part.
2. A cardiac center regulating the rate of the heart, through both accelerator and inhibitory fibers.
3. A respiratory center, controlling the muscles of inspiration.
4. A diabetic center, having to do with the conversion of glycogen to sugar.
5. An articulation center, which controls the coördination of the muscles involved in speech.
6. Centers for insalivation, mastication, swallowing, and vomiting.

Functions of the Spinal Cord.—*Conduction.*—As will be inferred from the above, the conduction of messages is the function of the fibers in the cord. The columns of white matter seen in the cord do not show much difference anatomically but physiologically there is a great difference. By referring to Fig. 211 the limits of the columns may be noted.

The *direct or anterior pyramidal* tract and the *crossed pyramidal* tract convey motor impulses. The crossed pyramidal tracts come directly from the pyramidal cells in the cortex, and passing through the medulla, cross from one side to the other at the "decussation of the pyramids." Fibers of the direct pyramidal tract cross from one side to the other *below* the crossing of the "crossed" tract, so that all motor impulses come out on the opposite side to that in which they originate. The right side of the body is controlled by the left side of the brain. Motor impulses from the motor areas of the brain pass down these tracts to the motor cells in the anterior cornu of gray matter in the cord, thence going by spinal nerves to their peripheral terminations.

Sensory impulses from the periphery pass into the cord, then may go through any of several columns to the brain. The fibers in these tracts seem to cross from one side to the other in any part, so that section of half the cord produces anesthesia of the opposite side of the body below the cut.

Association and Augmentation.—This function of the cord is performed through the correlation neurons. Fibers go from one side

of the cord to the other side. They go up and down, carrying impulses to numerous areas, thereby multiplying or augmenting the reflex response. Different segments of the cord are thus brought into association.

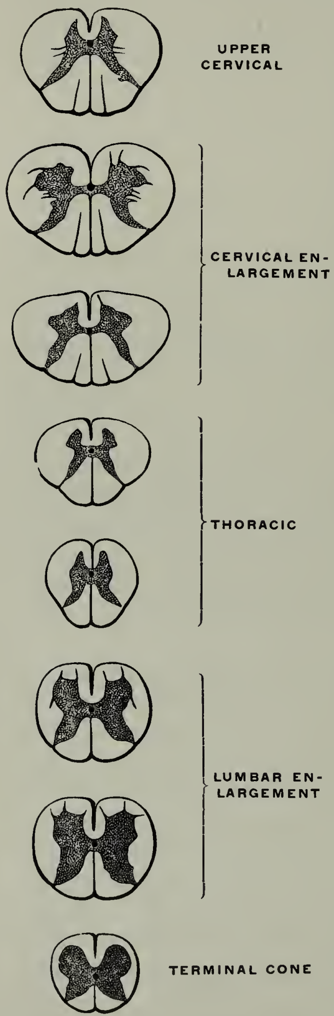

Fig. 231.—Transverse sections of the spinal cord at different levels. (Testut, after Erb.)

Transference.—Another function of the cord is the transference of impressions from one place to another, as, in the case of pain in the knee-joint when the trouble is really located in the hip-joint.

Reflex Action.—This is one of the very important functions of the cord, and takes place without the mediation of the brain, though as seen above, reflexes occur with the centers in the brain, as well.

For a reflex act to occur, the so-called "reflex arc" must be intact.

Reflex Arc.—A reflex arc consists of a receiving neuron to which some stimulus comes *via* the sensory fibers in a cranial or spinal nerve; the association of the branches of this neuron with the branches of a motor neuron, from which a message goes out through a cranial or spinal nerve to the periphery. If all the parts of this arc are intact, a reflex can occur, but if any part is impaired, the reflex is lacking. Not only may this reflex affect a voluntary muscle, but it may also influence the vasomotor and other nerves of the sympathetic system. The number of reflex actions that occur through the spinal cord is very large. Certain tracts in the cord seem to be devoted to these actions. (See page 252.) It is not incorrect to say that life is a series of reflex actions, since there would be nothing done by or in the body if afferent impulses did not go to the brain and spinal cord, there to be sent by the association fibers to some motor center.

The reflex contraction from various muscles may be obtained by a quick blow on their tendons. Several superficial reflexes that form a part of a routine physical examination may be noted.

Knee-jerk or Patellar Tendon Reflex.—Upon giving a quick blow to the ligamentum patellæ, between the patella and the tubercle of the tibia, with the knee relaxed in a flexed position, there occurs a spasmodic extension of the leg, or a contraction of the quadriceps extensor muscle. This reflex is present in health, but may vary in degree. If any part of the *arc*, sensory or motor, is diseased no reflex occurs. In infantile paralysis and locomotor ataxia it is absent.

Ankle Clonus.—Pressing upon the sole of the foot so as to flex the ankle suddenly and to vigorously stretch the gastrocnemius and the tendo Achillis, there results a rapid and rhythmic extension of the foot. This reflex is not present in health.

Heart Reflex.—Upon striking the spine of the seventh cervical vertebra several light blows, there is an increase in the tone of the heart muscle, as well as of those of the bloodvessels and hollow viscera. (Abrams.)

Special Centers.—Through the reflexes, certain centers in the cord regulate many acts, as defecation, micturition, etc. Through stimulation of various parts of the spinal cord and the mediation of the rami communicantes, the involuntary muscles of various organs as the heart, stomach, intestines, and bloodvessels may be made to contract or relax.

Coördination and Automatic Action.—Certain voluntary actions, such as walking, writing, etc., by many repetitions become so entirely familiar, the cord attends to their performance without the mediation of the brain.

Trophic Functions.—As the integrity of a part is dependent upon its activity, and the activity is dependent upon its nerve supply, degeneration or destruction of nerve cells in the cord results in trophic changes in the peripheral parts. Breaking-down of tissue may accompany or result from interference with the normal impulses from the appropriate spinal centers.

QUESTIONS.

Name the coverings of the brain and spinal cord.
Of what use is the cerebrospinal fluid?
Name the divisions of the brain.
Compare the functions of the cerebrum and cerebellum.
What is meant by "motor areas" of the cortex?
What are afferent nerves?
What is a "reflex"?
Describe "unconditioned reflexes."
What structures are necessary to a reflex action?
In what part of the brain is the "respiratory center"?
Describe the gray matter of the spinal cord.
How is a spinal nerve formed?

In what direction do motor influences pass in the spinal cord and nerves?

What is meant by "column" in the white matter of the cord?

Name the functions of the spinal cord.

What are "rami communicantes"?

What general region receives its motor supply from the brachial plexus?

From what plexus does the innervation of the diaphragm come?

What is the principal nerve coming from the sacral plexus, and what muscles receive motor impulses from it?

NOTE.—While the nervous system, physiologically, is an indivisible unit, for the sake of rendering it a little more easily comprehensible, the portion especially concerned with the voluntary muscles is here placed in the chapter immediately following that subject.

The consideration of the sympathetic or autonomic portion is placed in a new chapter immediately following the discussion of the organs which are controlled through those nerves.

CHAPTER VIII.

THE CRANIAL NERVES AND THE ORGANS OF SPECIAL SENSE.

THE CRANIAL NERVES.

From the under surface of the brain, 12 pairs of nerves emerge to be distributed to the following structures. They are indicated by number as well as having definite names (Fig. 206). Of the 12, the first and second contain only afferent fibers; third, fourth and sixth have efferent fibers only; the fifth, ninth and tenth have both afferent and efferent fibers; the seventh, eleventh and twelfth only efferent, and the eighth only afferent fibers.

First pair. *Olfactory,* or nerve of smell is distributed to the upper part of the nasal cavity.

Second pair. *Optic,* or nerve of sight, is distributed to the eyeball as the retina.

Third pair. *Oculomotor,* is distributed to the eyeball muscles, with the exception of the external rectus and the superior oblique.

Fourth pair. *Trochlear,* goes to the superior oblique muscle of the eyeball, with motor impulses.

Fifth pair. *Trifacial,* supplying the front of the scalp, the external ear, the cheek, teeth, gums, and front of tongue with sensation, and the muscles of mastication with motor impulses.

Sixth pair. *Abducent,* a motor nerve to the external rectus of the eyeball.

Seventh pair. *Facial,* supplying motor impulses to the superficial muscles of the face and to some of those of the throat.

Eighth pair. *Auditory,* the nerve of hearing and equilibrium, distributed to the labyrinth of the internal ear.

Ninth pair. *Glossopharyngeal,* the nerve of taste, distributed to the tongue, with fibers of ordinary sensation, and some motor fibers to the tongue and pharynx.

Tenth pair. *Vagus* or *Pneumogastric* nerve has a very extensive distribution, passing from the base of the brain, through the neck (under the sterno-cleido-mastoid muscle), the thorax, the diaphragm into the abdomen. It is partly sensory, partly motor, partly cerebrospinal, partly autonomic.

It receives branches from the *spinal accessory,* the *facial,* the *hypoglossal,* and the first two cervical nerves. These modify its action upon the parts to which it is distributed.

Afferent fibers carry sensations from the mucous membranes of the esophagus, larynx, trachea, lungs, stomach, and intestines.

These fibers assist in maintaining the automatic functions of respiration, cardiac activity, and blood-pressure.

Efferent preganglionic fibers pass by way of sympathetic ganglia to the plain muscle fibers of the esophagus, stomach, intestines, bile duct, bronchial tubes, and heart.

They have an inhibitory effect upon the heart, slowing its rhythm.

Motor fibers go, also, to the striated muscles of the pharynx and larynx, influencing the coördination in swallowing.

Stimulation of the vagus increases vasomotor tone in general. (Page 333.)

Eleventh pair: *Spinal accessory,* sending motor fibers to the trapezius and sterno-mastoid muscles.

Twelfth pair: *Hypoglossal,* the motor nerve of the tongue.

THE ORGANS OF SPECIAL SENSE.

The Optic Nerve and the Eye.—The eyeball and its appendages are placed in the orbital fossa, in a bed of fat and areolar tissue. It is not perfectly spherical, having a slight increase in the curvature at the *cornea,* in front, and a slight flattening behind. The eyes can turn in various directions, upward, downward, inward, and outward, as well as obliquely by means of four recti muscles, with two oblique. These muscles are partly under the control of the will and partly of autonomic reflexes.

On the outside of the eyeball is a dense white fibrous covering, the *sclerotic.* On the front of this is a clear transparent structure like the crystal of a watch, called the *cornea.* Inside the fibrous structure is the *choroid,* a network of blood-vessels which contains much dark pigment. Applied to the back of the sphere is the spread-out nerve of sight, the *retina.* Filling the sphere, keeping it from wrinkling and so interfering with sight, is a transparent, jelly-like mass, the *vitreous.* This keeps the eyeball plumped out, yet elastically firm.

Back of the cornea is the *crystalline* lens, a bi-convex structure that is perfectly transparent. (Fig. 232.) It is surrounded by a capsule which is tightened by the contraction of the ciliary muscle. The lens, with the cornea and vitreous humor, refract the light that enters through the pupil. Experiment with a "burning glass" will illustrate the refraction of light.

Between the cornea and the lens hangs a curtain with a hole in it, which corresponds in use and appearance with the diaphragm of a camera. The curtain is the *iris,* varying in color with different individuals, and the hole is the pupil, which becomes larger or smaller, according to the amount of light thrown into it. The space

between the cornea and the iris is the anterior chamber of the eye, which, with the posterior chamber back of the iris, contains the aqueous humor, a watery material which is refractive.

The eyelids cover the ball, and attached to their edges are the cilia or lashes. The eyelids close as a reflex when one sleeps, when a sudden very bright light occurs, on the contact of an object with the cilia, when sneezing, and every so often to clear the eye by renewing the film on the cornea. Blinking or the rapid closing and opening of the eyes improves the vision by lessening the tendency to stare at objects. Lining the lids and covering the exposed surface of the eyeball is a mucous membrane, the *conjunctiva*.

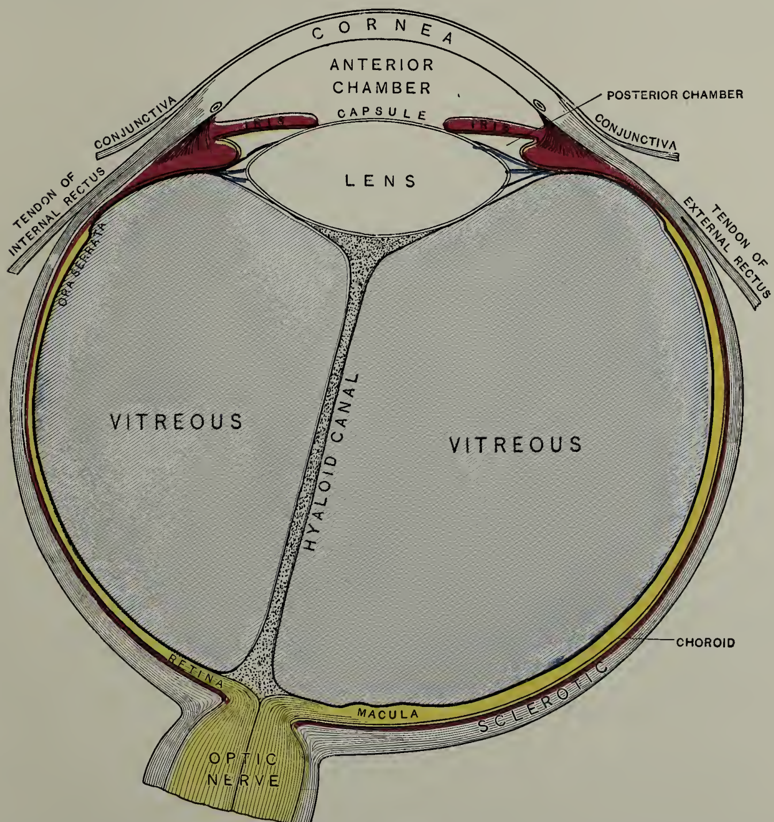

Fig. 232.—The right eye in horizontal section, showing the upper surface of the lower segment. Diagrammatic. (Testut.)

At the inner border of the lower lid is the opening of a tube, that leads into the nasal cavity, and carries the tears and any small particles from the surface down into the nose. This is the *lachrymal* duct and the little gland that secretes the tears is the lachrymal

gland. The tears keep the eyeball moist. Their secretion is increased in cold, strong winds, by emotional states, and by acrid inhalation, as from onions. The eyes are closed by the contraction of the *orbicularis palpebrarum*, a muscle that surrounds the eye.

The normal stimulus of the retina is light. This is admitted through the pupil, refracted by the cornea, lens, aqueous and vitreous humors, received upon the retina, and then as visual images carried by the optic nerve to the cortex of the brain. These images give rise to the sensations of sight as being modification of light. Parallel rays of light coming from an object are refracted so their image falls on the retina in an inverted position, but through experience we have learned to imagine things in their proper position, in spite of the upside-downness of them. (Fig. 233.)

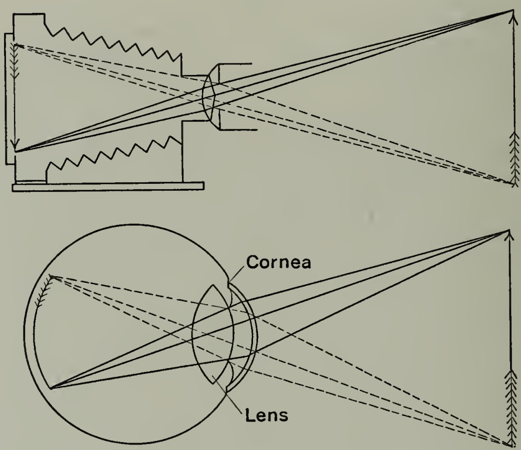

FIG. 233.—Note that in the camera the lens changes the direction of the ray of light, and in the eye the same change is seen twice—once through the lens, and again through the cornea.

In the camera, if nearby objects are to be photographed, the distance between the lens and the sensitive plate is increased and *vice versa.*

In the eye, if accommodation is made for near objects, the distance between cornea and retina is increased.

Accommodation.—The pupil reacts to light and to distance. The more light there is thrown into the eye, the smaller the pupil becomes An object brought nearer to the eyes causes the pupil to diminish in size. If it is placed at a greater distance the pupil opens wider.

At 20 feet or more the rays of light coming from objects are practically parallel. From nearer objects, down to 3 inches, the rays become more divergent. In order to have a clear image from such objects the eyes must "accommodate." In this process the eyeballs turn inward and increase in length, and the pupils become smaller.

Innumerable theories have been advanced to explain "accommodation." That which claims an increase in the antero-posterior diameter of the lens by the contraction of the ciliary muscle, has been largely accepted despite the observed fact that many who have had the lens removed are able to accommodate. Another theory explains it as due to the increase in the antero-posterior diameter of the eyeball by the action of the superior and inferior oblique muscles.

Six muscles are attached to the eyeball. Four recti—superior, inferior, internal and external—turn it respectively upward, downward, inward and outward. This includes turning the cornea. The superior and inferior obliques form an almost complete belt

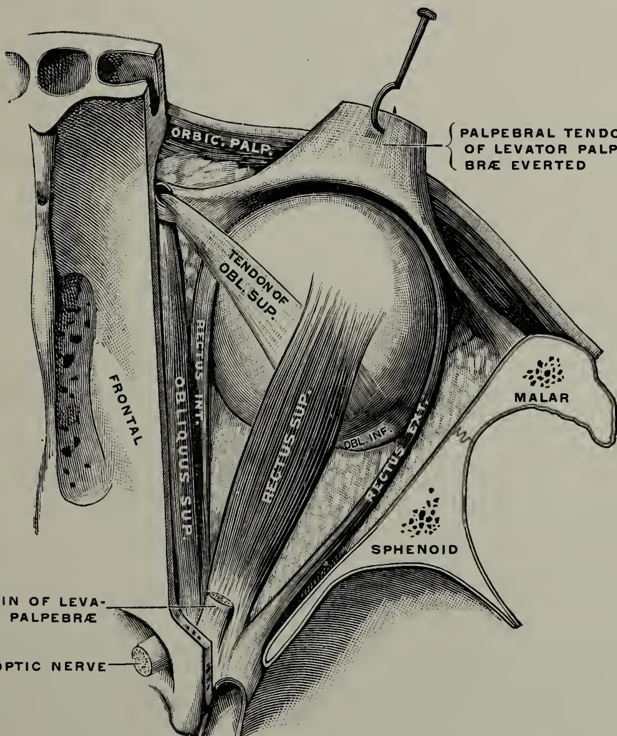

FIG. 234.—Muscles of the right eye, viewed from above. (Testut.)

around the equator of the eyeball. When they contract the eyeball lengthens. It is, apparently, by their action that the "lensless" eye (probably, too, the normal eye) can accommodate. (Fig. 234.) The pupil of the eye is always contracted during sleep, when under the influence of morphine, during chloroform and ether anesthesia, accompanying great anguish, and in injuries to the cervical spinal cord.

The pupils dilate when light is suddenly turned off; when accommodation is made for distant vision; in some emotional states, as fear, horror, dyspnea, at the time of dying; from the effect of midriatics, as belladonna, cocaine; in extreme nervous exhaustion; in glaucoma; in concussion of the brain; and from excessive secretion of adrenalin.

In a normal, *emmetropic* eye the image of an object comes to a focus on the retina. In a long, *myopic* eye the image falls in front of the retina. In the short, *hypermetropic* or *presbyopic* eye the image is formed back of the retina. These changes in the length of the eyeball can be produced by strain and relieved by relaxation.

The eye possesses the power of merging the two images received by each. These images vary slightly, on account of the distance between the two eyes. Details of depth and distance are imperfectly perceived by one eye alone, but become clear by binocular vision. The *retina* is, practically, the spread out optic nerve. Its structure is exceedingly delicate and complex. All parts are not equally sensitive to light, the most acute sight being at a small spot, called the *fovea* centralis, situated in the axis of the eyeball.

The nerve supply of the extrinsic muscles is partly from the cerebrospinal, partly from the parasympathetic of the autonomic system. The ciliary muscle is controlled by the parasympathetic.

The Auditory Nerve and the Ear. The eighth or auditory nerve is divided into *acoustic* and *vestibular portions.*

The acoustic portion or auditory nerve proper is concerned with the sense of hearing, *i. e.,* the appreciation of sounds within a limited range of vibration.

The vestibular portion of the nerve has to do with equilibrium, *i. e.,* the appreciation of balance and changes in the position of various parts of the body.

The *organ* of *hearing* is divided into the external, the middle, and the internal ear.

The External Ear.—The external ear is a flaring cartilaginous structure, which collects the sound waves and focuses them into the external auditory meatus, a tube about $1\frac{1}{2}$ inches long, leading to the partition between the external and middle ear. This tube is the epithelial lined auditory canal in the temporal bone. The cells of the lining secrete cerumen or wax. This wax catches dust and any small insects that attempt to get into the ear. (Fig. 235.)

At the inner end of the meatus is a membrane that separates the external and middle ear. It is the *membrana tympani.*

The Middle Ear.—Back of this membrane is a space, the *tympanum,* which in addition to air contains three small bones or ossicles, the *malleus, incus,* and *stapes.* These are arranged in a series, with the malleus in contact with the membrana tympani, and moved by its vibration; the incus unites the malleus and the stapes. The stapes connects the others to the opening between

the middle and internal ear, the *fenestra vestibuli* (formerly *ovalis*). Sound waves throw the membrana tympani into vibrations, which are transmitted by the chain of bones through the fenestra vestibuli to the perilymph within the bony labyrinth.

The Eustachian Tube.—Opening into the tympanic cavity is a tube, about 1½ inches long, which extends to the back of the pharynx. This is the Eustachian tube, carrying air from the throat to the middle ear, so as to equalize the pressure within and without the ear, on each side of the membrana tympani.

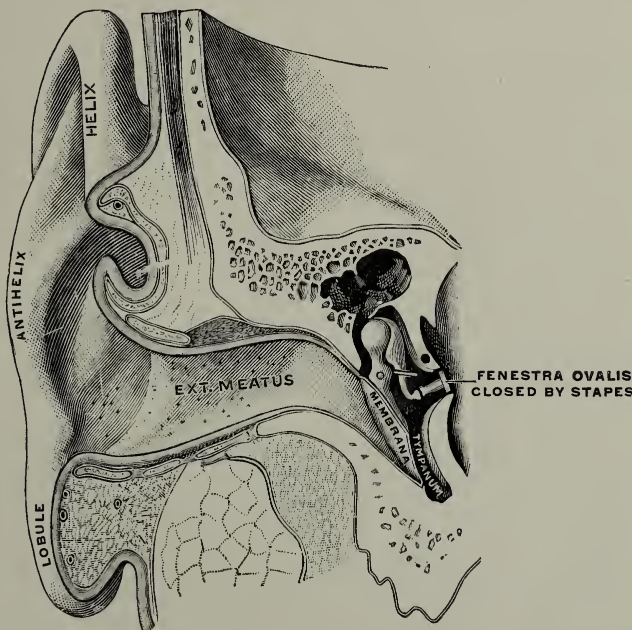

Fig. 235.—Vertical section through the external auditory meatus and tympanum passing in front of the fenestra ovalis. (Testut.)

The Internal Ear, or Labyrinth.—The internal ear begins back of the fenestra vestibuli. It is the essential part of the organ of hearing, as it receives the final distribution of the two parts of the auditory nerve. (*Acoustic and vestibular.*)

The labyrinth consists of two structures, the bony labyrinth and the membranous labyrinth. The bony portion begins at the medial side of the fenestra vestibuli (formerly called the "fenestra ovalis"), as an open space, the vestibule. From this space arises three semicircular canals, and a cochlea. (Shaped like the shell of a snail.) These bony cavities are hollowed out of the temporal bone. The walls are lined with an epithelium which secretes a fluid called the perilymph. In the cochlea, the disturbance of the fluid by the transmission of vibrations through the chain of bones in the middle

ear initiates changes in the eighth nerve which are interpreted by the cortex as sound. The perilymph communicates with the cerebro-spinal fluid.

The membranous labyrinth is of the same shape, but smaller than the bony labyrinth in which it hangs. Within the vestibule, it forms two cavities, the *utricle* and the *saccule.* From this last, the membranous coiled process extends into the bony cochlea. Upon the inner wall of the cochlea, the acoustic portion of the nerve is distributed. Here are those peculiar epithelial cells which "aid in the appreciation of certain sensory impressions."

Lining the membranous labyrinth, epithelial cells secrete the fluid called "endolymph."

The three semicircular canals are in three planes, one horizontal, and two vertical, at right angles with each other. The membranous canals have enlarged ends, called "ampullæ." To the utricule, saccule, and the ampullæ, the vestibular portion of the eighth nerve is distributed. Equilibrium is controlled by this portion of the nerve. This nerve is connected with many other nerve centers which affect the entire body.

It is said the nerve distributed to the saccule attends to linear, antero-posterior movements. That to the utricle to linear, lateral movements, while the canals attend to rotary movements.

In movements of the body the fluids contained therein move with it. This holds true of the endolymph. If we turn to the right, and the endolymph lags behind, we have learned to interpret this as a movement to the right although it feels like a movement to the opposite side. (This is analogous to the interpretation of reversed images as seen by the eye.)

Just how this is done is not clear. These organs give information to the higher centers in the cortex as to the position and movement of the head. Messages pass between the eye muscles and the nerves from the semicircular canals. A person being rapidly rotated until he is dizzy will have involuntary movements of the eyes in the direction opposite to the rotation.

Between the labyrinth and the entire muscular system there are nervous connections. By this means we are conscious of posture, and maintain an erect position in spite of the pull of gravity. This so-called "postural reflex" is not connected with the cerebrum, but with centers in the cerebellum.

Neuro-epithelial cells with waving hair-like processes are concerned in the final step, in both hearing and equilibrium. It is possible the bits of hard particles, the *otoliths,* found in the endolymph, may make pressure on these hairs when the head is placed in various positions, so initiating impressions that are translated into consciousness of changing postures. See also, "Kinesthetic Sense, page 277.

The Gustatory Nerve and the Tongue.—The tongue is the principal organ of taste and of articulate speech, helping in mastication and deglutition. It is highly sensitive to touch, heat and cold.

It is an index of the bodily health, showing the degree of elimination that is going on. It is occasionally a means of diagnosis, as its appearance is sometimes characteristic of special conditions. The tongue consists of a muscle, the *lingualis,* which has a median raphé, and is attached to the hyoid bone. Associated with it are several others, the genioglossus, the hyoglossus, the styloglossus and the chondroglossus muscles. A large variety of movements are possible to this combination.

The tongue is covered with a mucous membrane, the back part of which contains the "taste buds," or terminals of the gustatory nerve. (Fig. 236.)

All tastes may be classified as being either sour, sweet, bitter, or salt. Modifications of these primary characteristics are found that distinguish the flavor of articles. Lemonade, for instance, is both sweet and sour. Ginger ale added to it produces another flavor, partly by the sensation of stinging and partly by the impact of the bubbles of CO_2. The sense of touch and the sense of smell modify sensations of taste. The secretion of saliva aids in the appreciation of taste. The tip of the tongue appreciates sweet and sour tastes, while bitter things are recognized with the back of the tongue.

The Olfactory Nerve and the Nose.—The nose is a prominent part of the face, and is formed mostly of cartilage. The two nasal bones at the upper part, the vomer, and the ethmoid forming the septum, serve to support the cartilage.

The openings visible in front are the anterior nares, while those posteriorly which communicate with the pharynx are the posterior nares.

The nasal fossa contains three bodies, the superior, middle and inferior turbinated. The superior body is osseous, but the other two are cartilaginous. These bodies are scroll-shaped, providing a large extent of surface for mucous membrane. (Figs. 237, 238.) Lining the nose, the septum, the turbinated bodies and communicating with the similar lining of the naso-pharynx, the ethmoid cells, etc., is a mucous membrane, rich in bloodvessels. This is the Schneiderian membrane. On the area covering the superior turbinated bodies, the olfactory nerve is distributed. The epithelium over the nerve area is destitute of goblet cells, so not secreting mucus. There are columnar cells resting on several layers of nuclei, which belong to the olfactory nerve cells.

The Sense of Smell.—In man the acuteness of this sense is much less than it is in most animals. It is rather easily modified, as may be noticed when we easily ignore bad air in a room that at first was

offensive. As the sense of smell is located in the highest part of the nose, the currents of air passing through to the lungs do not generally affect it. This air goes through the lower portion which has a richer blood supply.

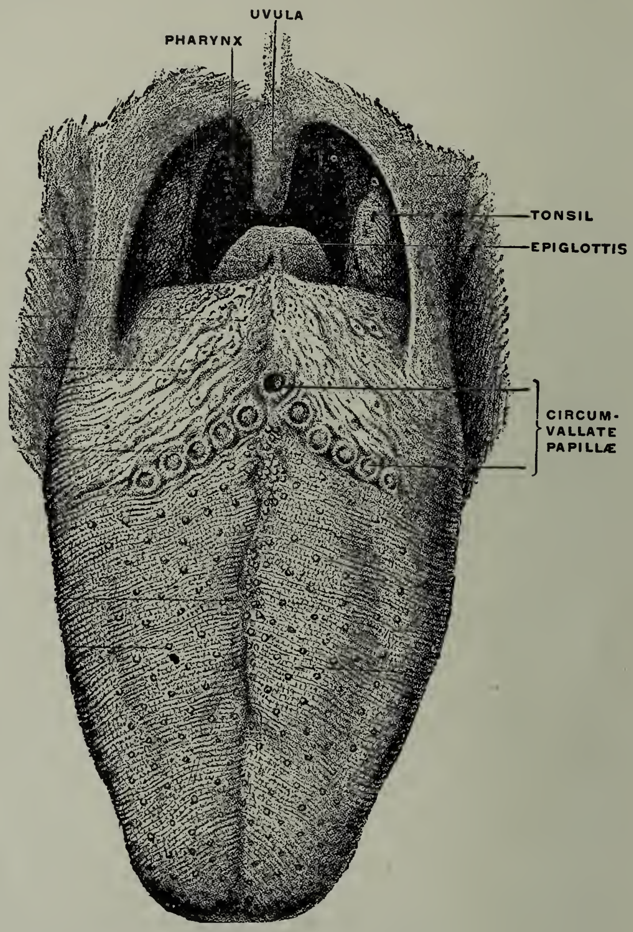

Fig. 236.—Dorsal surface of the tongue. (Testut.)

The nose is also a special external organ of respiration, and the intricate convolutions of the interior are to provide a large vascular surface by which the incoming air may be warmed before going into the lungs. (See also page 339.)

Nerves of Touch and General Sensation.—The special organ of the sense of touch is the skin. As the skin will be described in detail in connection with the organs of elimination, no description of it will be given here.

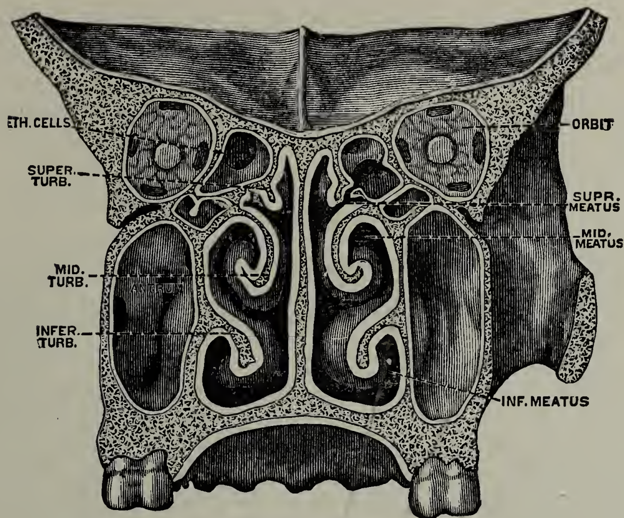

FIG. 237.—Coronal section of nasal fossæ at the plane of the second molar tooth seen from behind. (Hirschfeld.)

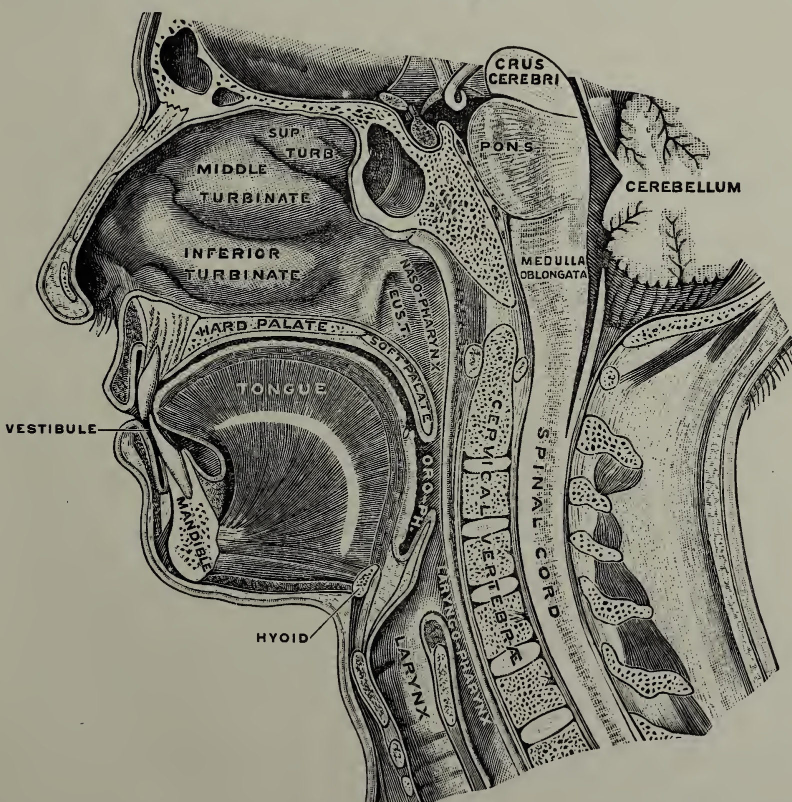

FIG. 238.—Sagittal section of face and neck, showing external wall of right nasal fossa. (Testut.)

The muscles, tendons and joints are supplied with sensory nerves from which is developed what is sometimes called the "muscular sense" or the kinesthetic sense, by which we are conscious of the position in space occupied by our members and the movements performed by them, etc. (See page 277.)

QUESTIONS.

Name the parts of the eyeball.

What is the pupil of the eye?

What correction must be made in our conception of images projected on the retina

What function has the Eustachian tube?

Can you tell what symptoms you might have if your semicircular canals were diseased?

How many uses has the tongue?

Of what use are the turbinated bodies?

What is the "kinesthetic sense"?

CHAPTER IX.

THE CIRCULATORY SYSTEM.

The blood in the body is contained in a system of closed tubes, into which two other tubes open. This makes for a continuous flow of blood from one part of the body to another, with varying amounts in the different regions at different times. The life of every part of the body is dependent upon an adequate supply of blood. There must be some way to insure the flow of blood as whatever amount there is in the tubes must answer for all needs.

The organs concerned are the heart, arteries, veins, capillaries and lymphatics. Two pumps, one of them a force pump, the other a suction pump provide the power to keep the blood in motion. The *force pump* is the *heart.* The *suction pump* consists of several mechanisms, not located in any one spot and to be described later.

THE ANATOMY OF THE HEART.

The heart is a hollow, muscular organ, located in the middle mediastinum, and forming the central reservoir for the blood, and it is also a pump. In shape it is bluntly conical, with the apex about the fifth intercostal space. The base is on the level of the upper border of the third rib. It extends about ½ inch to the right of the sternum, and approximately 3½ inches to the left of the mid-sternal line. (Fig. 239.)

The Pericardium.—The walls of the heart are made of cardiac muscle. It is covered by a layer of serous membrane which is doubled back to form a pouch-like structure. This sac has an outer fibrous investment which is attached to the diaphragm below, to the cervical fascia above, and to the pleuræ covering the lungs on each side. This covering is the *pericardium.* It is applied loosely to the heart, and invests part of the large vessels leaving the heart. A serous fluid is secreted which serves to prevent friction, as the heart swings back and forth.

The chambers of the heart are two ventricles and two auricles, placed above the ventricles. It is practically true to say there are two hearts, the right and the left, as they do not communicate with each other, though the auricles open into their corresponding ventricles.

Leading out from the right ventricle is a large tube, the pulmonary artery, while the aorta leads out from the left ventricle. The

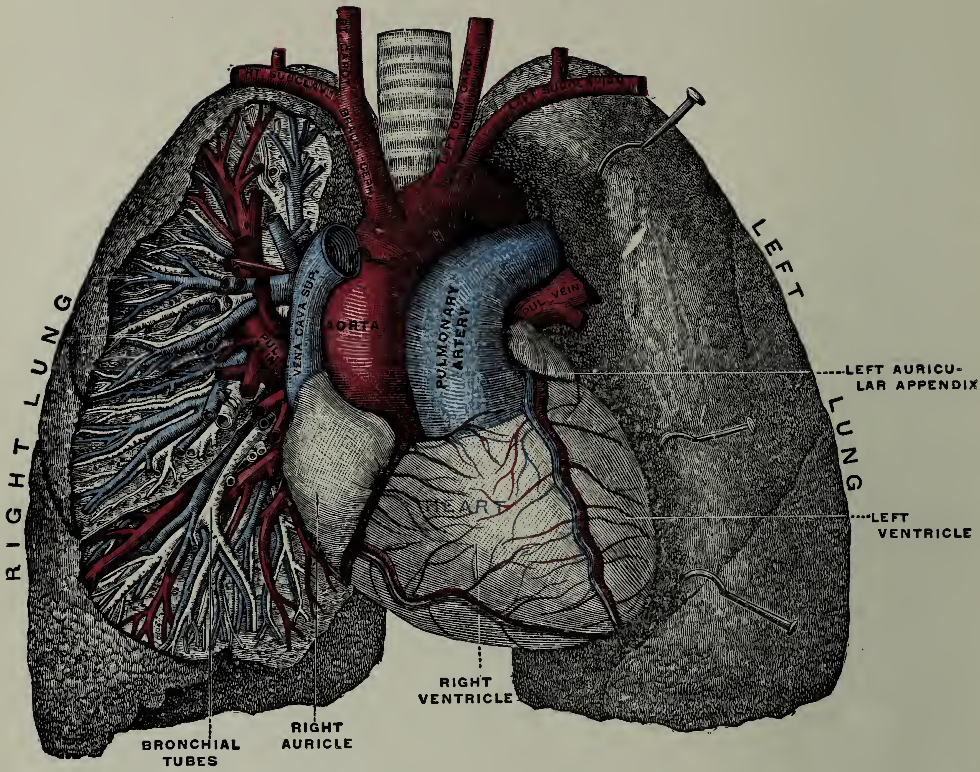

FIG. 239.—The pulmonary artery and aorta. The front part of the right lung has been removed, and the pulmonary vessels and the bronchial tubes are thus exposed. (Testut.)

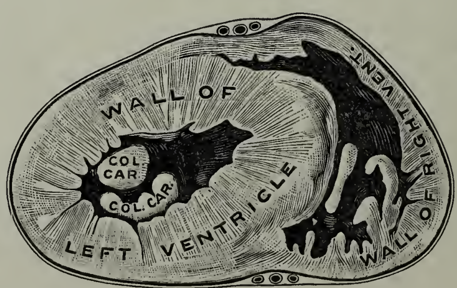

FIG. 240.—Cross-section through both ventricles, showing the shape of their cavities and the relative thickness of their walls. (Testut.)

right auricle has opening into it two large tubes, the superior and the inferior vena cavæ. The left auricle has opening into it four pulmonary veins.

There is much difference in the thickness of the walls of the two ventricles, the left having the greater amount of tissue. This is required on account of the greater amount of work done by the left ventricle. (Fig. 240.)

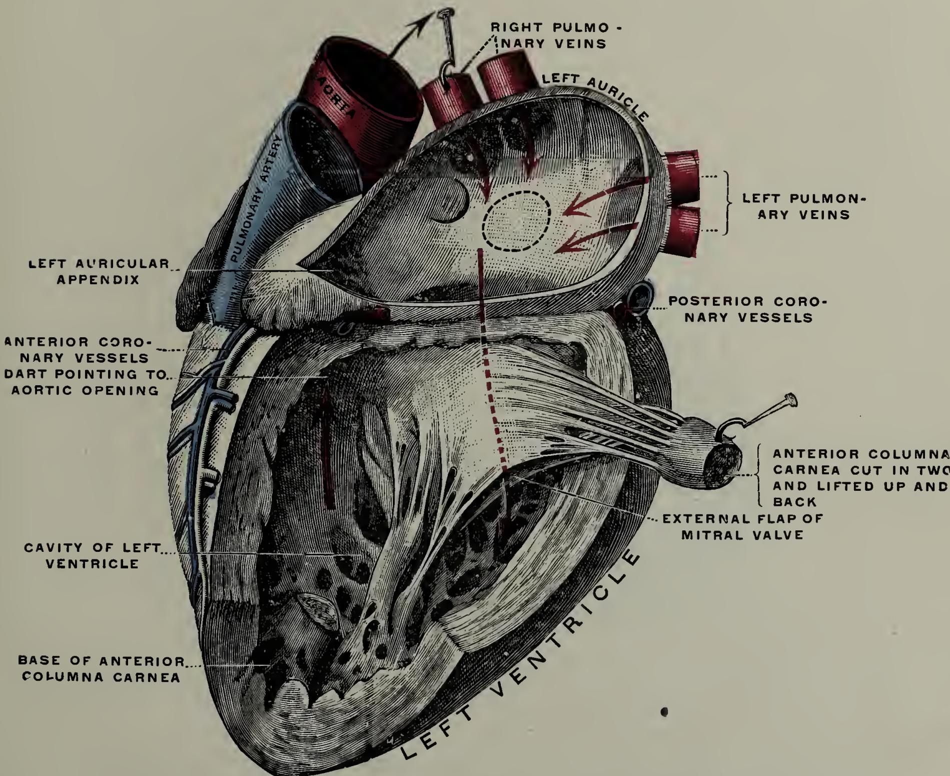

Fig. 241.—Left auricle and ventricle, the hind wall of each having been removed. (Testut.)

Columnæ Carnæ.—The inner surface of the ventricle presents a series of fleshy projections. These are the columnæ carnæ. (Fig. 241.) They seem like additional supports to the walls.

Valves of the Heart.—The openings between the auricles and ventricles, and those between the heart and its large vessels are closed by movable fibrous valves. These open to let the blood pass through, but close to prevent a backward flow of blood. On the right side of the heart the opening between the right auricle and right ventricle is closed by the *tricuspid* valve. On the left side

the corresponding valve is the *mitral.* The opening between the right ventricle and the pulmonary artery is closed by the pulmonary valve, with the aortic valve in the corresponding position on the left side. These valves being half-moon shape are called "semilunar." (Fig. 242.) Running between the auriculo-ventricular valves and the columnæ carnæ are delicate fibrous cords, the *chordæ tendineæ.* Lining the cavities and the valves of the heart is a delicate serous membrane, the *endocardium.* The endocardium is thin and smooth. By foldings upon itself it helps to form the valves of the heart. Continuous with it is the lining of the blood-vessels. This consists of a layer of epithelial cells on a base of connective tissue containing elastic fibers as well as white fibrous tissue. Small vessels, called the *coronary* arteries, and the coronary veins supply the heart muscle with nutrition and carry off the wastes.

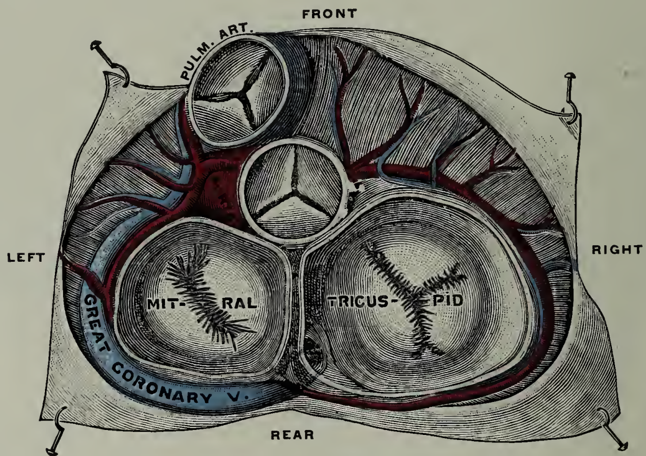

Fig. 242.—Valves of the heart and great arteries, viewed from above, the auricles having been removed. (Testut.)

THE ANATOMY OF THE ARTERIES.

Arteries are the tubes by which the blood is carried *from* the heart. The quality of the blood does not matter, that is, whether it is pure or impure, aërated or unaërated. If the vessel comes from the heart it is an artery.

As the blood leaves the heart with considerable force, the arterial walls must be strong enough to withstand it. As it comes in spurts, the walls must be elastic enough to stretch and afterward recoil, returning to their normal size. The walls must provide for changes in the caliber of the vessel, so it may be made smaller on occasion. And, it must present no obstruction to the flow of blood by reason of roughness of the lining.

To provide for all these contingencies, arteries have three coats, or tunics. On the outer side is a white fibrous layer, with some yellow elastic fibers. The middle coat has plain muscle tissue, with some yellow elastic tissue. The inner coat is an epithelial layer, with a small amount of yellow elastic tissue.

The elasticity of the arterial walls is marked, especially in the larger ones. There is considerable variation in the relative amounts of fibrous and muscular tissues, the largest arteries having less muscular but more fibrous tissue. The smaller arteries have more muscular and less fibrous material, while the middle-sized arteries have about equal quantities of each.

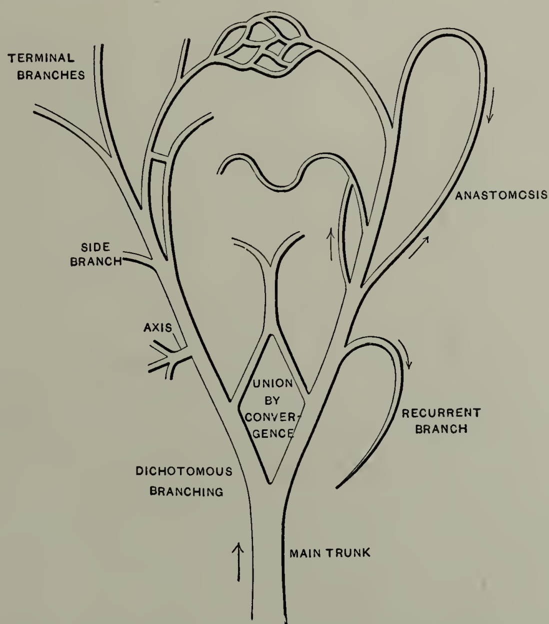

Fig. 243.—Diagram showing the branchings, anastomoses and confluence of arteries. (Gerrish.)

Divisions of an Artery.—From the heart, two large arteries are given off. These two divide and subdivide, branching in every direction like a tree. (Fig. 243.) As the arteries divide they become smaller, but when the cross-sections of all the branches are considered, the sum total is much more than that of the original trunk. This is widening the bed of the arterial system, and as in any stream under such circumstances, the rate of flow is decreased.

Arteries communicate very freely with each other. The greater the need for blood, the more the arteries anastomose or communicate. This is a provision for a sufficient supply of blood in every

position, whatever muscles are contracting. If an artery must be ligated, the anastomosis of the part will supply a sufficient amount of blood.

In an artery which supplies an extremity, the trunk which enters the limb sends off branches from the side; it may send a deep or superficial branch that is as large as the original; it will send direct articular branches to the joints and recurrent branches going back to nourish the joint when the direct supply is shut off by muscular contraction or position; it will send off branches to anastomose with the anastomosing branches of other arteries, and send a nutrient artery to the bone. It will also send off small arteries the *vasa vasorum* to nourish the walls of the larger ones

When arteries have divided and subdivided until they are microscopic in size, they have lost most of the fibrous covering, much of the muscular coat, but have retained all the epithelial tunic. They are then called "arterioles." (Fig. 244.) Arteries lie in a bed of areolar tissue, usually accompanied by the nerve that supplies the same part, and the vein that drains it. The arterioles divide into still smaller vessels, losing all the coats except the epithelial. The vessels are now microscopic in size and are called *capillaries.*

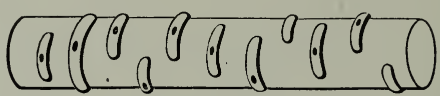

Fig. 244.—Diagram of the arrangement of muscle cells in an arteriole. (Gerrish.)

THE ANATOMY OF THE CAPILLARIES.

The single layer of epithelium forming the wall (Fig. 245), will allow the materials of the blood plasma to pass through it into the spaces around the microscopic cells, and the waste materials in the spaces to pass into the capillary. The length of a capillary is microscopic, and its diameter so small that in some the red corpuscles can pass through them in single file only. Their size varies, those in the lungs being the largest in the body. Those in muscle tissue are placed between the fibers in areolar tissue. (Fig. 29.)

Capillaries are either arterial or venous. When the flow is toward the tissue cells the capillaries belong to the arterial system; the flow in them is away from the heart. When the direction of the flow turns toward the heart the capillaries are venous. They take on additional coating. When the capillary acquires a small amount of additional tissue it becomes a venule or venous radicle. This unites with another venule, and these with another, until several have united in a single vessel, which is then a vein.

Small veins unite to form larger veins, until finally two trunks,

the venæ cavæ, superior and inferior, discharge all the venous blood into the right auricle. The number of veins is greater than that of arteries, so that it is possible for the veins to contain all the blood in the body, leaving the arteries empty. The rate of flow in the veins being slower than that in the arteries, more room is required to accommodate it. An artery is often accompanied by two veins, the "venæ comites."

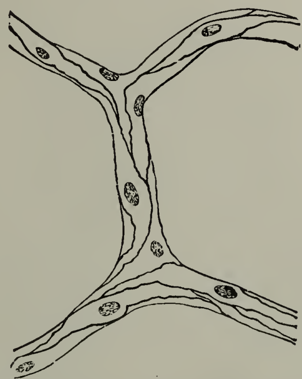

Fig. 245.—Capillaries, showing the shape and arrangement of the cells which make their wall. (Carpenter.)

THE GENERAL CIRCULATION OF THE BLOOD.

In an endless chain, it is difficult to select a place for breaking in. In the circulation of the blood through a system of closed tubes, one must start somewhere, though there is no beginning to be found. By reference to Fig. 246 and following the arrows as the description proceeds, a clear idea of the general circulation may be obtained.

Starting with the left ventricle, the contraction of the heart throws blood into the aorta. The aorta sends off branches (systemic arteries) which divide and subdivide like the branchings of a tree, until the arterioles are reached, and then the capillaries in the body tissues (systemic capillaries).

The capillaries then become venous radicles, they in turn collecting into larger veins (systemic veins), until finally the stream passes into the right auricle.

From the right auricle the blood goes into the right ventricle, and the contraction of the heart sends the blood into the pulmonary artery which divides and subdivides like the branchings of a tree, until the pulmonary capillaries are reached. These capillaries are in the lung structure. The capillaries then lead into veins, which unite into the pulmonary veins which pass the blood into the left auricle, from which it flows into the left ventricle, to start the journey again.

THE CIRCULATORY SYSTEMS.

There are four circulatory systems: (1) The *general,* or *systemic,* consisting of arteries, veins and their connecting capillaries, by which the arterial blood with oxygen and nutritive food products in it is carried to all parts of the body, with the return to the heart, *via* the veins, of this blood, plus CO_2 and the nitrogenous waste from the cells in general.

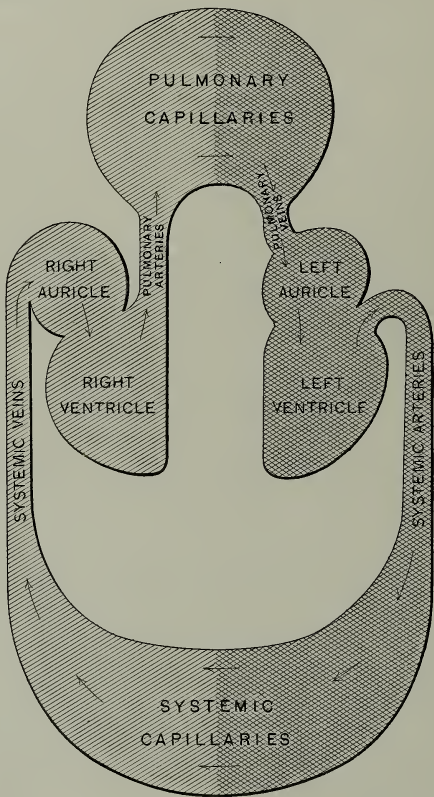

Fig. 246.—Diagram to show the course of the blood in passing from a given point through the two sets of capillaries to the starting-point. (Gerrish.)

2. The *pulmonary circulation,* in which the blood containing CO_2 and waste materials from the systemic circulation is sent by the pulmonary artery to the lungs. Here the CO_2 is removed, and a new supply of O is taken on, after which the blood returns to the left side of the heart by the pulmonary vein.

3. The *renal circulation* in which the blood goes from the left heart to the kidneys in which the nitrogenous wastes (urea) is removed. The purified blood then returns to the right side of the heart.

4. The *portal circulation* in which venous blood (part of which carries new food products) gathered from the stomach, pancreas, spleen and intestines are taken by the portal vein into the liver. (Fig. 293.) Here in the laboratory cells of the liver, sugar is taken from the blood and stored in the liver cells as glycogen; nitrogenous waste materials from the work of the cells added to the products of intestinal putrefaction, such as skatol, indol, etc., are converted into urea, which goes back into the blood. This blood, united with that drained from the liver by the hepatic vein, goes to the right side of the heart *via* the inferior vena cava.

Each of these four systems thus contribute toward the regeneration of the circulating vital fluid. All the blood in the body must pass through these systems in turn.

If a vertical line is drawn through Fig. 246, the right half colored blue and the left half colored red, it would show that the right heart deals with unaërated blood only, while the left heart deals with aërated blood only.

THE GENERAL ARRANGEMENT OF THE ARTERIES.

It is evident that the bloodvessels are everywhere in the body since the smallest gash cannot be made through the skin without drawing blood. So wonderfully is the network of arteries arranged, that if the direct blood supply of any part is cut off, there are other ways, through anastomosis by which the part may be supplied.

Divisions of the Pulmonary Artery.—The pulmonary artery leaving the right ventricle divides into right and left pulmonary arteries, passing into the respective sides of the lungs. They break up in the lung substance, like the branchings of a tree, until the capillaries are reached. The exchange of O and CO_2 occurs between the minute air cells of the lungs and the capillaries. CO_2 is given off, and O is taken on by the red corpuscles of the blood. Then the formation of little veins begins, which join others, until there are four pulmonary veins that empty into the left auricle.

Divisions of the Aorta.—The aorta is the largest artery in the body. It leaves the left ventricle and forms an arch toward the back and left.

The first branches are two *coronary arteries* which provide nutrition for the heart itself. The large arteries that come off next supply the head, upper extremity and the walls of the chest. First, the innominate or brachio-cephalic arises on the right side, and immediately divides into the *right common carotid* and the *right subclavian.* Next, the left common carotid and the left subclavian arise from the arch. (Fig. 239.) The aorta now turns downward, and opposite the lower border of the fourth thoracic vertebra its name becomes the thoracic aorta. (Fig. 247.)

Continuing through the thorax it sends branches that supply the structures within the thorax and its walls. Reaching the diaphragm it passes through it and becomes the *abdominal aorta*. (Fig. 254.) Many large branches are given off which supply the viscera within the abdominal cavity, the diaphragm and the walls of the cavity.

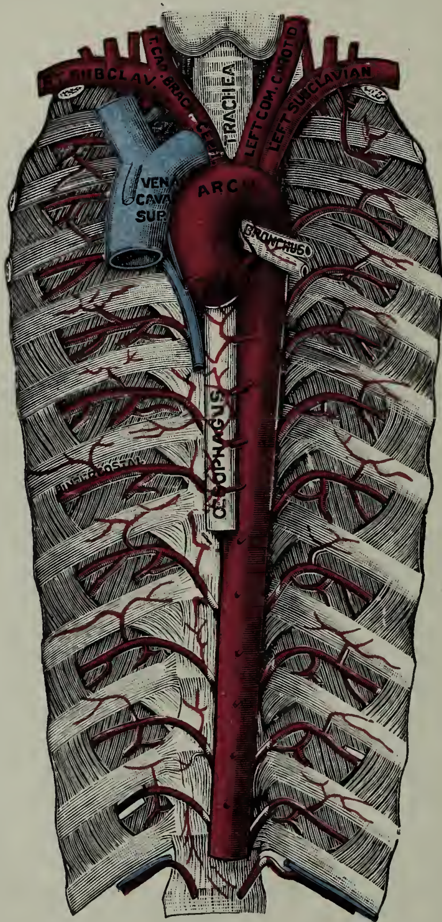

Fig. 247.—Thoracic aorta. (Testut.)

At the level of the fourth lumbar vertebra, the abdominal aorta divides into the *right* and *left common iliac arteries*. A little further, on, at the level of the articulation of the last lumbar with the first sacral vertebra, the common iliac divides into the *internal* and *external iliacs*.

The internal iliac artery on each side goes into the pelvis and supplies the pelvic viscera and walls, the external genitals, the structures about the hip-joint and the inner part of the thigh. The

external iliac artery goes out of the abdominal cavity into the thigh, and becomes the *femoral artery*. (Fig. 255.) Two-thirds of the way down the thigh it becomes the *popliteal.*

The *popliteal* artery passes through the popliteal space. At the lower edge of the popliteus muscle dividing into the *anterior* and *posterior tibial* artery, which by dividing and subdividing supply the leg and the foot.

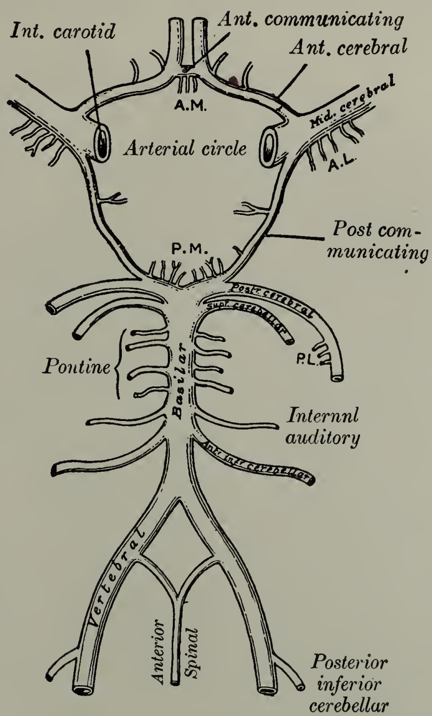

FIG. 248.—Diagram of the arterial circulation at the base of the brain. *A.L.*, antero-lateral; *A.M.*, antero-media; *P.L.*, postero-lateral; *P.M.*, postero-medial ganglionic branches. (Gray.)

Carotid Arteries.—Going back to the branches first given off, the common carotids on each side, as they pass up the side of the neck, divide into the *internal* and *external carotids*. This division takes place at the level of the upper part of the larynx. The artery is here associated with the internal jugular vein and the vagus nerve.

The *external carotid* artery passes upward behind the angle of the jaw, sending off numerous branches. These form four sets. The first set supplies the thyroid gland, the tongue, structures about the mouth, and adjacent muscles. The second set passes posteriorly to supply the occipital region and the external ear. The third set supplies the pharynx and tonsils, with branches to numerous

20

small muscles in their vicinity. The fourth set goes to the parotid gland, the muscles of the face, the temporal muscles, and the external part of the eye.

The *internal carotid* artery enters the cavity of the skull through an opening in the petrous portion of the temporal bone. It sends off many branches to the various structures within the cranium. At the base of the brain, its branches anastomose with branches of the *basilar* artery, to form the "arterial circle of Willis." From this

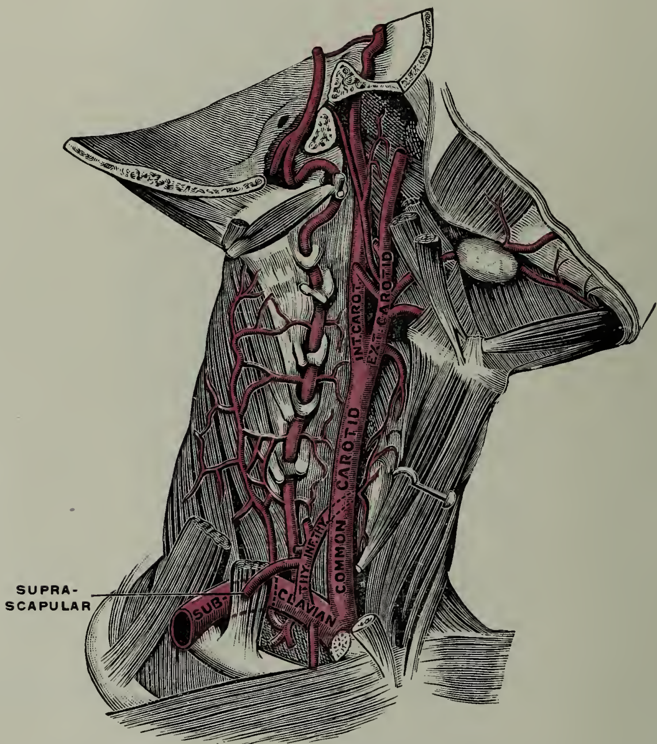

Fig. 249.—Right subclavian and carotid arteries. The vertebral artery is seen threading the costotransverse processes of the vertebræ. (Testut.)

circle, the *anterior*, *middle*, and *posterior cerebral* arteries pass out to supply the corresponding areas of the brain substance, including the cortical areas. A peculiar feature of these arteries is the lack of anastomosis between them. They neither send out nor receive branches to join other branches. If an artery becomes blocked, the portion of brain substance supplied by that artery deteriorates, as no other supply is available.

Branches go to all parts of the brain and to the eyes. (Fig. 248.)

Subclavian Artery.—Soon after its beginning, the subclavian artery sends off a branch, the *vertebral.* This ascends through the foramina in the transverse processes of the lower six cervical vertebræ, passes behind the upper articular process of the atlas to enter the skull through the foramen magnum. (Fig. 251.) It unites with its fellow of the opposite side to form the basilar artery. Branches supply the structures within the spinal canal and the deep muscles of the neck.

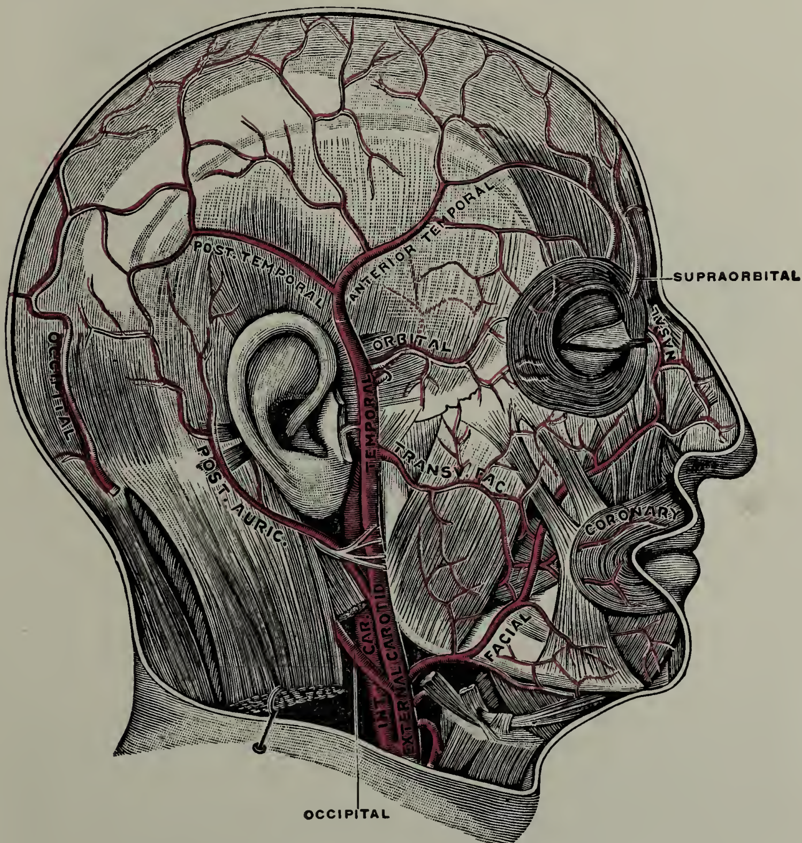

FIG. 250.—Superficial arteries of the head. (Testut.)

Other branches of the subclavian are the *internal mammary* going to the mediastinum, muscles on the chest wall, and the mammary gland; the *thyroid axis,* supplying the gland of the same name, and the *superior intercostal,* distributed to the posterior vertebral muscles. (Fig. 249.)

The Axillary Artery.—The subclavian passes toward the outer side of the shoulder and opposite the lower border of the first rib becomes

the *axillary*. The branches given off from the axillary go to the structures about the shoulder-joint and the side of the chest. (Fig. 251.)

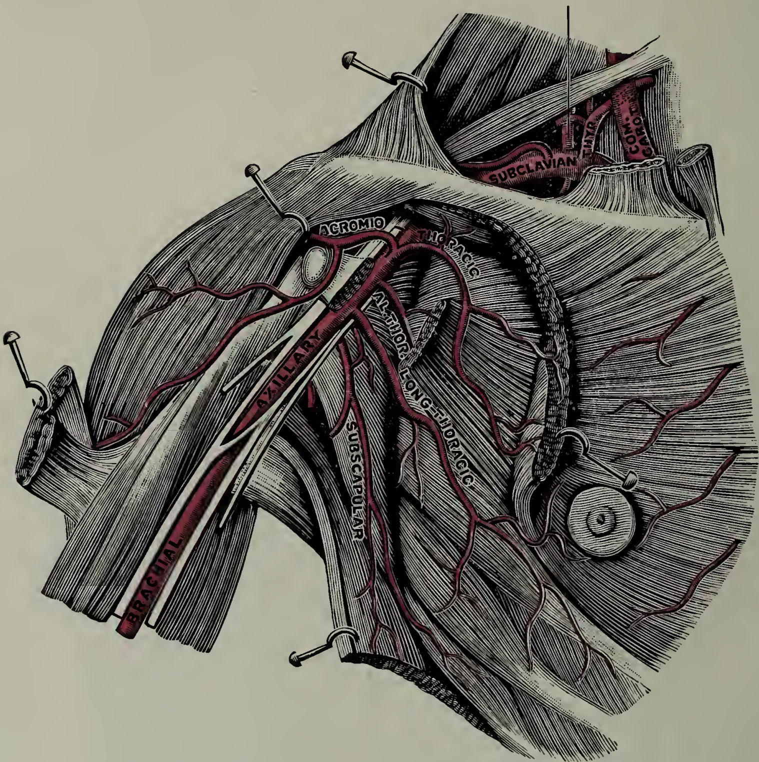

Fig. 251.—Axillary and subclavian arteries. (Testut.)

At the lower margin of the *teres major muscle* the artery enters the arm and becomes the *brachial*. The inner side of the biceps marks the location of the artery, with its accompanying vein and the median nerve. The deep branch supplies the triceps, brachioradialis, the brachialis, and the deltoid. A nutrient artery to the humerus passes off about the middle of the arm. Branches go to the shoulder-joint and elbow-joint. Above the latter, the artery sends branches to anastomose with branches from the radial and ulnar arteries.

It may be understood that as a general thing, the arteries that supply a joint supply also the muscles that move the joint and the skin over them.

Just below the elbow the *brachial* divides into the *radial* and *ulnar arteries*. (Fig. 252.) The *radial artery* passes along the

outer side of the forearm to the wrist, sending branches back to the elbow-joint, to the wrist, the muscles on the radial side of the forearm, the radius, the thumb, and the index finger. It winds backward, on the outer side of the wrist to the space between the first and second metacarpal bones. It passes into the palm, crossing it and uniting with a branch of the *ulnar* artery to form the deep palmar (or volar) arch. (Fig. 253.)

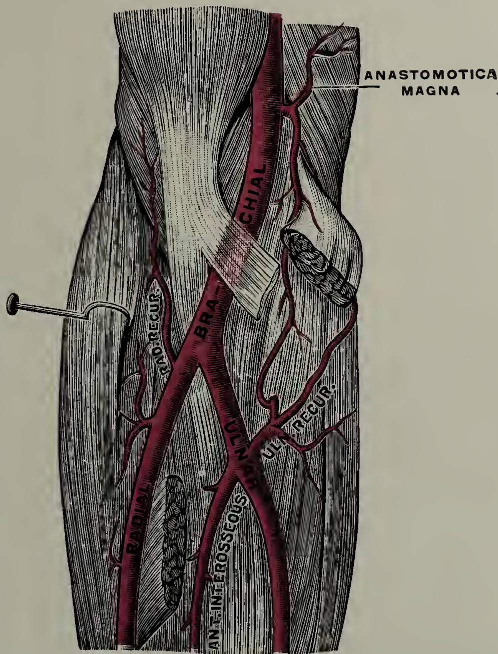

FIG. 252.—Arteries in the region of the bend of the elbow. (Testut.)

The *ulnar artery* passes through the inner side of the forearm to the wrist, and divides into two branches, which unite with branches of the radial to form the deep and superficial palmar arches. The artery crosses the palm before joining the branch of the radial, making the reverse arrangement to that in which the radial crosses the palm in the deep arch. It supplies the muscles on the inner side of the forearm, the wrist, the ulna, the skin, and sends branches back to the elbow-joint and the contiguous muscles.

The *palmar arches* give rise to branches that pass through the palm and fingers, supplying the muscles, joints, and skin, anastomosing with each other.

The Thoracic Aorta.—The thoracic aorta is contained in the mediastinum, extending from the level of the fourth thoracic vertebra

to that of the twelfth. It lies near the vertebral column. The branches from it are all small, being distributed to the pericardium, to the substance of the lungs as the *bronchial* arteries, to the esopha-

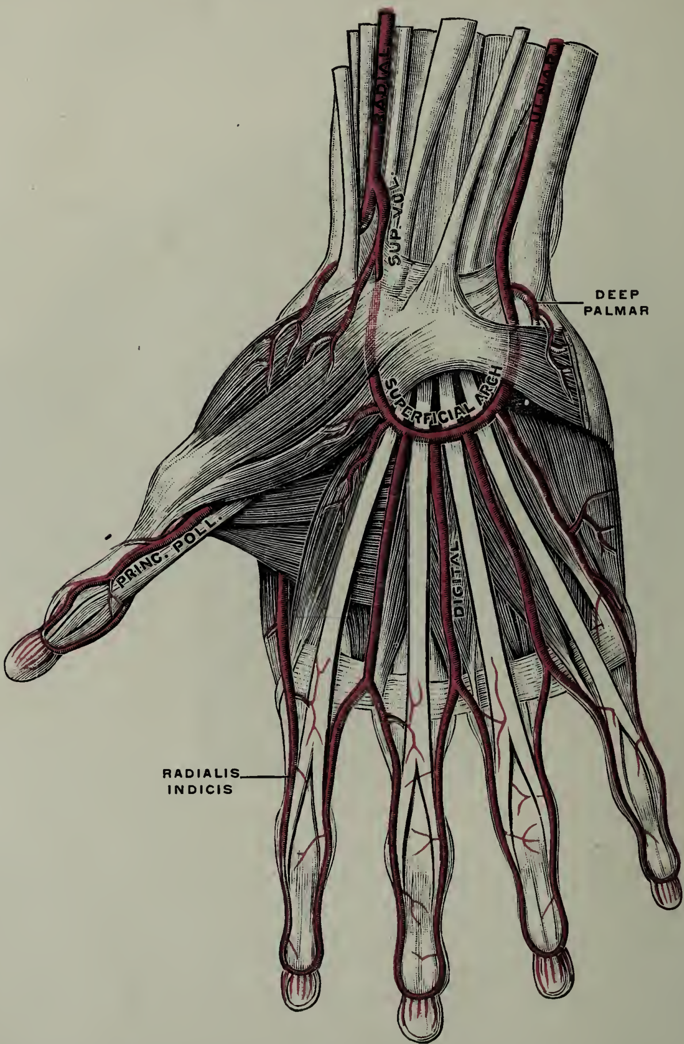

Fig. 253.—Superficial palmar arch and its branches. Of the digitals, only the third is labeled. (Testut.)

gus, to the lower nine intercostal spaces, to the intercostal muscles, the pectoralis major and minor, and the serratus anterior.

At the diaphragm the aorta passes through just in front of the spine, becoming the abdominal aorta.

The Abdominal Aorta.—The abdominal aorta sends off a number of branches. Just below the diaphragm is a short trunk, the *cœliac axis,* from which the *gastric* artery for the stomach, the *hepatic* artery for the liver, and the *splenic* or *lienal* artery for the spleen pass off.

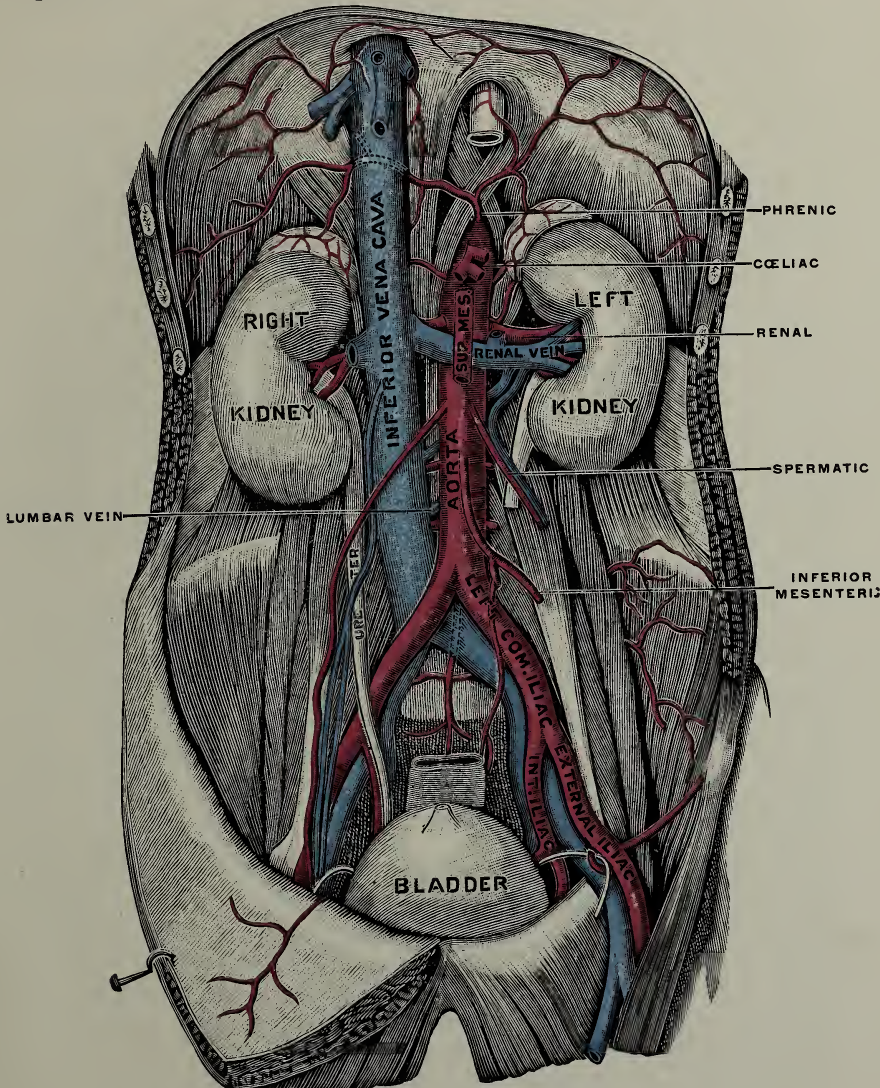

Fig. 254.—Abdominal aorta. (Testut.)

These three main arteries branch and send off anastomosing vessels which supply the viscera in the upper abdomen, as follows:

The *suprarenal* artery supplies the suprarenal glands.

The *superior mesenteric* supplies the upper intestine, with the lower intestine supplied by the *inferior mesenteric.*

The *renal* artery supplies the kidneys.

The *ovarian* artery supplies the ovaries.

The *phrenic* artery supplies the diaphragm.

The *lumbar* arteries go to the deep muscles of the back.

At the level of the fourth lumbar vertebra the abdominal aorta divides into two *common iliac* arteries.

The Common Iliac Artery.—The common iliac artery is short, being about 2 inches in length. It sends off a few branches to the peritoneum, the ureters, the psoas magnus muscle, and surrounding areolar tissue. Opposite the articulation, between the last lumbar vertebra and the sacrum, it divides into the internal and external iliac arteries.

The Internal Iliac Artery.—The internal iliac artery, or the *hypogastric* artery, is a short vessel which sends off branches to supply the walls and viscera of the pelvis, the buttock, the inner side of the thigh, and the generative organs, before dividing into two terminal branches. The anterior branch supplies the bladder, rectum, uterus, vagina, and the obturator muscles, gluteus maximus, the external rotators of the thigh, and the muscles attached to the tuberosity of the ischium. The posterior branch supplies the iliac muscle, the ilium, the skin and muscles on the back of the sacrum, and the gluteal muscles.

The External Iliac Artery.—This artery passes along the border of the psoas magnus to the point midway between the anterior-superior spinous process of the ilium and the symphysis pubis. Here, it becomes the *femoral* artery and enters the thigh. It supplies some of the abdominal muscles and the skin over them. It makes communication with many arteries above and below, even with the branch of the subclavian known as the internal mammary.

The Femoral Artery. (Fig. 255.)—This artery lies in front of the hip-joint at the upper part of its course, then passes to the front and inner side of the thigh, finally passing through the adductor magnus to become the popliteus. In the groin is a three-cornered space in which lie the femoral artery and vein, with the femoral nerve. This space, called "Scarpa's triangle," is just internal to the inner edge of the sartorius muscle. The artery is easily reached from this place.

Superficial branches supply the skin over the upper thigh and the lower abdomen. Branches pass to the femur, to the sartorius, the vastus medialis, the adductors, and to the hip-joint. A deep branch, which is about as large as the main artery, goes to the back of the thigh to supply the hamstring muscles. In addition, articular

branches supply the knee-joint, anastomosing with branches of the popliteal and the tibial arteries.

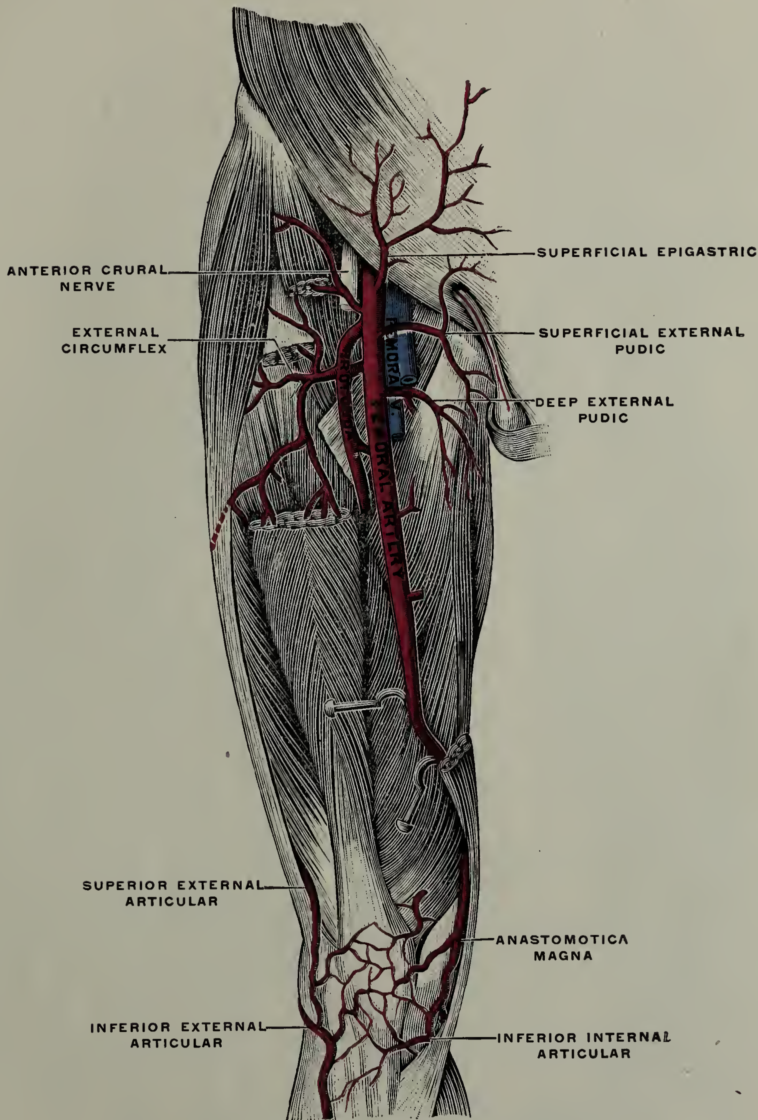

Fig. 255.—Femoral artery. (Testut.)

The Popliteal Artery. (Fig. 256.)—The popliteal artery passes through the adductor magnus muscle at the junction of the middle and lower thirds of the thigh. It passes behind the knee-joint, in

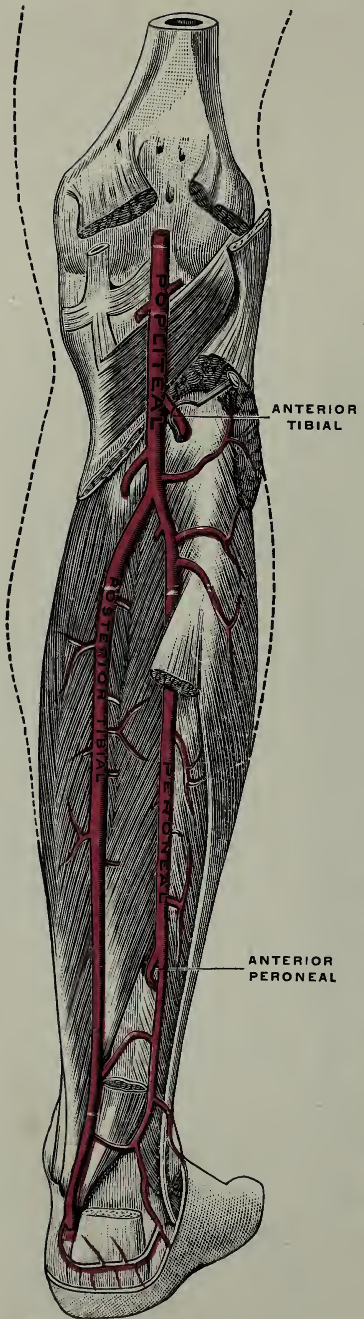

Fig. 256.—Arteries in the dorsal part of the leg. (Testut.)

Fig. 257.—Arteries in the sole of the foot. (Testut.)

the "popliteal space," and at the lower border of the popliteal muscle divides into two branches, the *anterior tibial* and the *posterior tibial* arteries.

The *popliteal space* is a lozenge-shaped space, bounded above on the outer side by the biceps femoris and below by the plantaris and outer head of the gastrocnemius. On the inner side are the semitendinosis, the semimembranosus, and the inner head of the gastrocnemius. The floor is formed by the oblique ligament of the knee-joint, the popliteal surface of the femur, the upper end of the tibia, with the fascia that covers the popliteus. The space contains, besides the artery, the corresponding veins and nerve, the small saphenous vein, some lymph glands, and fat. To prevent interference with the blood supply when the knee is flexed, there is a profuse anastomosis, from branches above and below the knee.

Among the muscles supplied by the popliteal artery are the adductors, hamstrings, gastrocnemius, soleus, and plantaris. The knee-joint is supplied, together with the skin over it.

The Anterior Tibial Artery.—From below the popliteal space, the anterior tibial artery goes forward and downward to the deeper part of the leg. It descends on the interosseous ligament, then on to the front of the ankle, where it becomes the *dorsalis pedis.* It sends branches back to the knee-joint, supplies the soleus, peroneus longus, tibialis anterior, extensor digitorum, and peroneus tertius. The ankle-joint is supplied by this artery.

The *dorsalis pedis,* on the dorsum of the foot, divides into branches that supply the tarsal bones and joints, and the small muscles connected with them. These branches supply the great toe, and that next to it. As in the hand, the branches of this artery, together with the terminal branches of the *posterior tibial,* form two arches, one deep, the other superficial, from which arise the vessels supplying the toes.

The Posterior Tibial Artery. (Figs. 256 and 257.)—As its name implies, the posterior vessel goes to the back of the tibia, thence to the inner malleolus, where it divides into the *medial* and *lateral plantar* arteries. Nutrient arteries supply the fibula and the tibia, muscular branches go to the soleus, tibialis posterior, flexor longus hallucis, and the peronei. It joins with the branches of the dorsalis pedis in forming the superficial and deep plantar arches. Both tibial arteries supply the ankle-joint and take part in the anastomosis around it.

THE ANATOMY OF THE VEINS.

The veins are the tubes that carry blood *to* the heart. This holds good regardless of the state of the blood as to aëration. The walls of the veins do not need to withstand the shock of a force pump but they need to be as strong as those of an artery. They lack the

stiffness of arterial walls, and when emptied, collapse immediately, whereas an artery remains patulous even if it is very small. There is considerable variation in the walls of veins. The inner coat is always the same, an epithelial layer, with minute folds in it called valves. These prevent the backward flow of the blood. As it starts backward, it runs in behind the folds of the valves and pushes them open, and thus closes the lumen of the vessel. (Fig. 258.) The middle coat of the veins contains but little muscular tissue, but some fibrous material. The outer coat is white and yellow fibrous tissue.

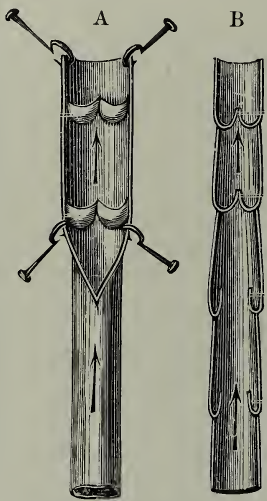

Fig. 258.—Valves of veins. A shows a vein cut open between the segments of two valves. B shows appearance of valves closed and open. (Testut.)

THE GENERAL ARRANGEMENT OF THE VEINS.

The veins in returning the blood from the peripheral parts to the heart are in two sets, the superficial and the deep, with frequent communicating veins between the two sets.

Systemic Veins.—The deep veins usually accompany the artery and the same name is given to both, as the hepatic artery, *hepatic vein,* the brachial artery is accompanied by the brachial vein, the femoral artery by the femoral vein, etc.

Variations from this rule occur in the names of the veins draining the brain and external cranium, in the venæ cavæ, and in the superficial veins of the upper and lower extremities.

The substance of the brain which is supplied by the internal carotid artery is drained by veins having the same names, which accompany the arteries. For instance, the cerebral arteries are accompanied by the cerebral veins. After the blood is collected from the various areas of the brain, these veins open into sinuses.

These sinuses are large, open channels in the two layers of the dura mater. They are lined by a layer of epithelial tissue which is continuous with that forming the inner coat of the veins.

These sinuses are between the two hemispheres, between the cerebrum and the cerebellum, and between the upper and lower parts of the brain. At the lower back part of the occiput, they unite in an enlarged space called the "torcular Herophili." From here, the transverse or lateral sinuses arise, and pass outward to the jugular foramen. In company with the inferior petrosal sinus, they enter the *internal jugular vein*. (The jugular foramen is a large opening in the skull between the occipital bone and the petrous portion of the temporal bone.)

This arrangement acts as a sort of safety-valve, as the arachnoid membrane covering the brain, under the dura, forms a water-bed to take up jars and pressure. If there should be any obstruction to the onflow of the venous blood, much of the resulting pressure would be absorbed by the water-bed. (Fig. 195.)

The *external jugular* vein drains the areas that are supplied by the external carotid artery, most of the small veins tributary to it having the same names as the corresponding arterial branches. (Fig. 259.)

The subclavian vein has collected the blood from the upper extremity, through the axillary, brachial, radial, ulnar, and the small branches opening into them, besides receiving the blood from the superficial veins of the upper extremity. The subclavian is now joined by the internal and external jugular veins, by the thoracic duct on the left side, the lymphatic duct on the right side, to form the innominate vein. The innominate receives the vertebral vein. The right and left innominates unite to form the superior vena cava. These veins lie close to the corresponding arteries, with the superior vena cava close to the arch of the aorta. In addition, the superior vena cava receives blood from the veins in the thorax.

The Superior Vena Cava.—This vessel is about 7 cm. long, beginning just below the cartilage of the first rib, and emptying into the right auricle of the heart at the level of the fourth thoracic vertebra.

The Inferior Vena Cava.—The blood from all parts of the body below the diaphragm goes into the inferior vena cava. This is collected from the lower extremities by the deep veins arising from the various plexi, on the foot, the leg, the thigh, and hip. That collected by the superficial veins, the pelvic veins, the abdominal veins, all, go into the common iliac veins. At the level of the sacro-lumbar articulation these two common iliacs unite and form the inferior vena cava. The portal vein joins the inferior vena cava, which corresponds to, and accompanies, the abdominal aorta. It passes through the diaphragm and through the pericardium into the auricle on the right side of the heart.

The Azygos Vein.—As it is necessary to provide adequate arterial blood for all parts of the body, the arterial system has numerous anastomoses, so with the veins it is necessary that there should be many paths by which the blood can reach the heart. Numerous plexi in the course of the veins enable them to form similar anastomoses. Between the superior and inferior vena cava the azygos major establishes such a by-path. The azygos major is a single vein, without a "fellow of the opposite side," lying in the mid-

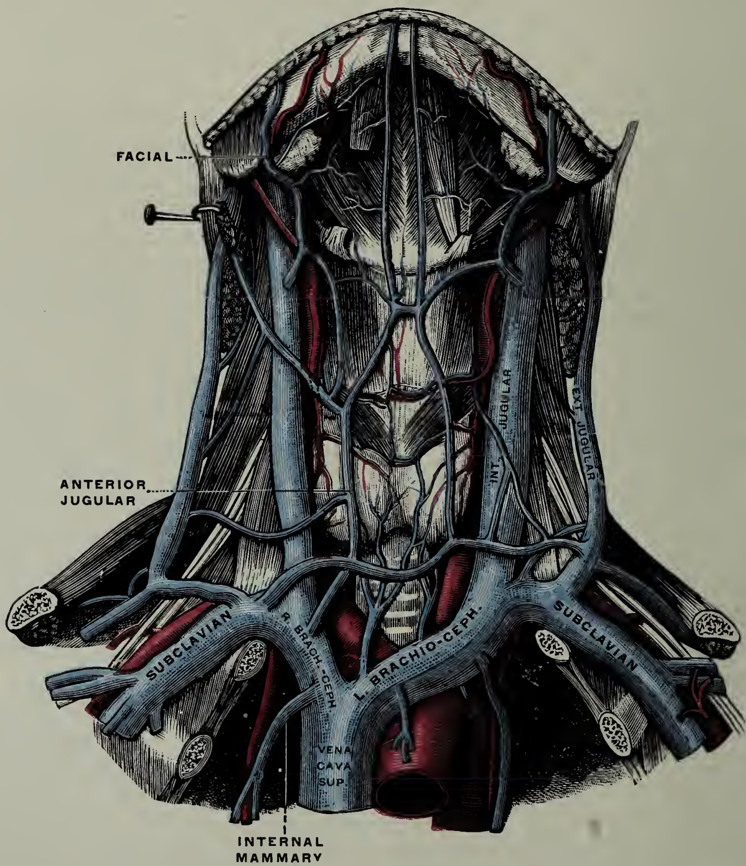

Fig. 259.—Veins of the neck and upper part of thorax, front view. (Testut.)

thorax and upper abdomen. It begins as a branch from the ascending lumbar vein, receives contributions from the intercostal veins, and several others, and, at the level of the fourth thoracic vertebra enters the superior vena cava just before that great vessel enters the heart. When the venous flow in the upper part of the body is obstructed, it is possible for the blood to make a detour through the azygos vein to the heart, as the two venæ cavæ are connected in this way.

One more vein should be mentioned, that which returns the blood from the heart substance. The *coronary sinus* accompanies the coronary artery, and ends in the right auricle.

At various points in the superficial veins the action of the valves may be observed. Place the finger of one hand at the junction of two veins on the dorsum of the hand. Then, with another finger, stroke the vein toward the wrist. This vein will be emptied, so it will collapse. As long as the first finger remains at its place, the vein remains empty. Remove it, and the blood instantly refills the vein. It had been held back by the valve.

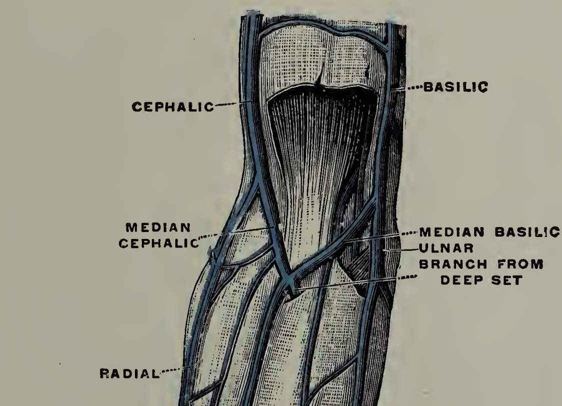

Fig. 260.—Superficial veins of front of forearm and lower part of arm. (Testut.)

Superficial Veins of the Upper Extremity.—The superficial or subcutaneous veins lie between the layers of superficial fascia, and are visible under the skin. They occupy the areolar tissue network which holds the skin to the underlying structures.

In the upper extremity the superficial veins form a network on the back of the hand, and a smaller network on the front of the

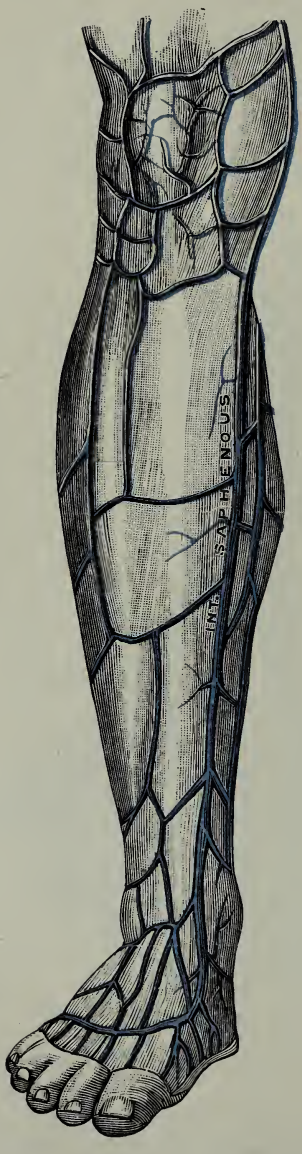

Fig. 261.—Superficial veins of the front of the leg and foot. (Testut.)

Fig. 262.—Superficial veins of the front of the right thigh. (Testut.)

wrist. Those on the back of the hand unite to form the *radial* vein which runs up the outer side of the forearm to just above the elbow where it joins the *median cephalic* to form the *cephalic*.

The *posterior ulnar* vein begins on the inner side of the network on the back of the hand, passes up to the elbow and there receives the *anterior ulnar*. This latter comes from the wrist along the inner side of the front of the forearm. These two ulnar veins form the *common ulnar* vein which joins the *median basilic* to form the *basilic*. The *median* vein starts from the plexus on the front of the wrist, goes to just below the elbow where it is joined by the *deep median* vein, and then divides into the *median cephalic* and the *median basilic*.

The *cephalic* runs up the outer side of the front of the arm, to the axillary, into which the basilic also empties.

Superficial Veins of the Lower Extremity. (Fig. 261.) — These veins have numerous valves to prevent the force of gravity interfering with the onward progress of the blood toward the heart. There are two main venous trunks, internal and external, which begin in a network over the instep and on the dorsum of the foot, called the dorsal plexus. This was formed by the veins from the toes, the inner and outer borders of the foot.

Long Saphenous Vein.—The *internal* or *long saphenous* vein begins at the inner part of the dorsal plexus (Fig. 261), passes up the inner side of the thigh nearly to Poupart's ligament, and there enters the femoral vein. It passes in front of the internal malleolus, and back of the internal condyle of the femur, and is joined by many superficial veins and numerous branches from the deep veins of the sole, leg and thigh. It contains from seven to twenty valves. (Fig. 262.)

Short Saphenous Vein.—The *external* or *short saphenous* vein begins at the outer part of the dorsal plexus, passes behind the external malleolus, and then on the outer and back part of the leg to the lower part of the popliteal space, where it joins the popliteal vein. It is joined by superficial veins from the foot, heel and back of the leg. It communicates with the internal saphenous, and has from nine to fourteen valves. (Fig. 263.)

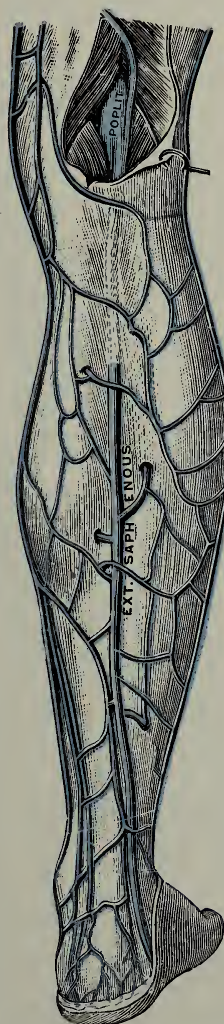

Fig. 263.—Superficial veins of the dorsum of the leg. (Testut.)

The Portal Vein.—A peculiar arrangement of the circulation is the portal system. The veins from the stomach, intestine, spleen

(lien) and pancreas unite to form the portal vein. This enters the liver, and breaks up into capillaries, and when the venous radicles are formed, they unite with those arising from beyond resulting from the *hepatic artery,* and pass out of the liver as the *hepatic vein,* going to the inferior vena cava. (See Fig. 292.)

Fig. 264.—Lymph vessel laid open lengthwise, showing arrangement of valves. (Gerrish.)

Fig. 265.—A lymph node with its afferent and efferent vessels. (Testut.)

THE ANATOMY OF THE LYMPHATICS, INCLUDING GLANDS. (NODES.)

Lymphatic vessels begin as the open ends of tubes in the spaces around the microscopic cells. These are "stomata" and the spaces in which they open are variously termed, "perivascular," "intercellular," "juice channels," "juice canals," "lymph spaces."

The lymph radicles unite to form larger tubes, which in turn unite to form still larger tubes, in the same manner as the veins. They decrease in number, but increase in size, though the lymphatics are not as large as the corresponding veins.

The wall of the smallest lymph radicle is epithelial tissue only, but as they go on they take two other coats, very like those of the

veins. The coats are so thin they are transparent. At very short intervals, the walls of the lymphatics are constricted by valves, formed by folds in the lining. (Fig. 264.) These are semilunar in shape. They prevent the backward flow of the lymph. No valves are present in the smallest lymph radicles.

The Lymph Nodes.—In addition to the tubes, the lymphatic system includes *nodes* or glands, which are placed at frequent intervals along the course of the vessels to filter the lymph and to add lymphocytes. These are bean-shaped masses of lymphadenoid tissue in whose meshes are many white corpuscles. (These white cells "wall off" infected areas, to prevent the spread of bacterial poisons.) Nodes sometimes have a fibrous capsule, and are easily identified. Sometimes they have no capsule, but are only infiltrated masses. (Fig. 265.) Passing into these glands are the lymphatic vessels from contiguous areas. There may be many of these *afferent* tubes, which have previously been the *efferent* vessels from glands further back in the circulation. (Fig. 265.) The two efferent vessels in the illustration will be afferent vessels to the next node.

Collections of nodes are found in the neck, axilla, groin, and abdomen, wherever deleterious substances are most apt to need fighting by the lymph corpuscles, *i. e.*, the white corpuscles or phagocytes. These nodes are superficial or deep, communicating with each other by the lymphatic vessels.

In the neck they are numerous under the chin and on the sides, under the angle of the jaw. They strain the material from the mouth, lips, cheeks, region of the ears. The deep nodes are located near the carotid artery and extend from the base of the skull to the clavicle. They drain the areas on the back of the head, around the ears, the mouth, nasal cavities, etc. (Fig. 266.)

In the arm there are few superficial nodes. One or two are just above the internal condyle of the humerus. Most of them are deep in the axilla, draining the arm, the skin, and muscles of the thoracic walls, and the mammæ. They communicate with the cervical glands. (Fig. 267.)

In the lower extremity there are several glands in the popliteal space. A larger number are in the groin, around the femoral artery and vein. They were either deep or superficial, draining especially the contiguous skin. As infection is likely to enter the body from outside, the superficial nodes are at the gateway.

In the abdomen the nodes are most numerous around the stomach, mesentery, and accompanying the large veins. They communicate with the nodes in the groin (inguinal) below and with those in the axilla. (Fig. 268.)

THE GENERAL ARRANGEMENT OF THE LYMPHATICS AND THE NODES.

The lymphatic ducts are similar to small veins in that they are very small at the beginning, until by uniting with others, large trunks are formed.

FIG. 266.—The lymph nodes of the neck and upper part of the thorax. (Testut.)

Theoretically, wherever the arterial capillaries have broken up about the tissue cells, with the exudation of plasma, there should be the beginnings of the lymphatic ducts. The fluid, with the added waste materials, must not be left in the perivascular spaces. However, so far, they have not been demonstrated as present in the substance of the central nervous system, its meninges, the kidney, spleen, liver lobule, internal ear, cartilage, and striated muscle. Virtually everywhere else they are present.

Lymphatic vessels are in superficial and deep sets. The first are in the subcutaneous tissues, forming a fine network. They

accompany the superficial veins. The deep vessels accompany the deep veins. In the thorax and abdomen the lymph channels are in the areolar tissue beneath the serous coat lining these cavities. In the respiratory, digestive, and genito-urinary tract they are in the submucous coat.

Fig. 267.—The nodes and vessels of the upper limb. (Testut.)

The Lacteals.—A special name is given to a group of lymphatics in the digestive tract. The villi of the mucous membranes, which contain blind ends of lymphatics, absorb the digested food products. These give a milky appearance to the ducts, and for that reason they are called "lacteals." It is only at the end of the digestive process that this appearance can be observed. At other times they look like the ordinary lymphatics.

The ducts in the right upper half of the body, the right side of the head, the heart, neck, chest, upper extremity, and the upper surface of the liver are all drained into the *right lymphatic* duct, which enters the right subclavian vein at its junction with the right internal jugular.

All other parts of the body drain into the *thoracic duct.*

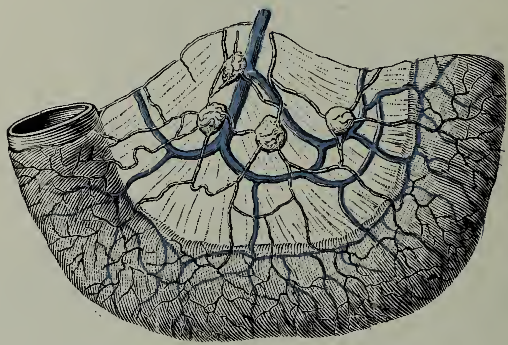

Fig. 268.—Mesenteric nodes. (Testut.)

The Thoracic Duct.—This begins in the abdomen just in front of the spine, on a level with the second lumbar vertebra. An expanded pouch, the *receptaculum chyli,* receives the contributions from the surrounding digestive organs. The duct then passes upward to the level of the fourth thoracic vertebra (a distance of from 15 to 18 inches), and there enters the left subclavian vein at its juncture with the left internal jugular. (Fig. 266.) The diameter of the duct is about that of a goosequill. Double valves guard the openings of both the right lymphatic and the thoracic ducts to prevent any regurgitation of lymph.

THE PHYSIOLOGY OF THE CIRCULATION.

The blood is the fluid that is carried to all parts of the body, and which carries in itself the nutrient material needed by every cell, the waste products from the working cells, and the secretions of the ductless glands.

The heart sends out about 4 ounces of blood at each contraction,

which occurs every .86 second, or on an average of 72 times a minute. This is the rate for the majority of persons, but within the limits of perfect health individuals may have a more or less rapid rate. At birth the rate is 135 per minute, decreasing to 88 by the fifth year. From ten to fifteen years the rate averages 78, then declining to 72, or less in advanced age. During exercise and digestion the rate is increased.

Systole and Diastole.—By the rhythmic contraction of the cardiac muscle, blood is sent from the heart. These contractions, constituting *systole,* alternate with periods of resting, called *diastole.*

The Cardiac Cycle.—The contraction may be likened to a circular wave that starts in the auricles in the upper part of the heart, at the entrance of the large veins, and passes downward to the lower part of the ventricles. After the auricles become filled with blood from the vena cavæ and the pulmonary veins, their systole begins, forcing the blood into the ventricles, through the auriculo-ventricular openings. This occupies about .16 second, after which their diastole occurs, lasting until it is time for the next contraction.

Immediately following the auricular systole is a brief pause while the pressure of the blood in the ventricles is raised, by the contraction of their muscle, to a point above the pressure in the large artery. Then, suddenly comes the ventricular systole in which the blood is thrown into the aorta and the pulmonary artery. This lasts .30 second, after which the ventricular diastole occurs, lasting .40 second. At the beginning of the auricular systole, the valves between the auricles and ventricles are open. As contraction continues, the valves are in a position midway between open and shut, while those between the ventricles and large arteries are closed. At the beginning of the ventricular systole, the mitral and tricuspid valves close, the aortic and pulmonary valves open. The diastole of the auricles begins .30 second earlier than that of the ventricles, thus allowing time for the blood from the large veins to flow into and fill the auricles, while the ventricles are still in systole.

With the ventricles in systole the auriculo-ventricular valves (mitral and tricuspid) are necessarily closed to prevent the regurgitation of blood from the ventricles into the auricles. The diastole or relaxation of the ventricles allows the weight of the contained blood in the auricles to open the auriculo-ventricular valves, and the blood to flow into the ventricles. With the auricular systole there is a complete emptying of blood from auricles to ventricles. The blood continues to flow into the two large arteries as long as the pressure in the ventricles is higher than that in the arteries. When, from the diminished amount of blood, the pressure falls, the higher pressure in the arteries causes the blood to start back toward the heart. This recoiling blood runs in behind the semilunar valves and closes them, so that during this rest period the auriculo-ven-

tricular valves are open and the semilunar valves (pulmonary and aortic) are closed. As the heart muscle is flaccid, there is no pressure exerted on the contained blood. The slight pressure in the venæ cavæ is sufficient to cause the blood to flow from them into the auricles and thence into the ventricles prior to the auricular systole. This alternation of systole and diastole is the *cardiac cycle.*

Apex Beat.—During contraction of the heart muscle, the fibers shorten, causing the base to move toward the apex. The hardness of tissue, due to this contraction, forces the chest wall slightly outward, so the impulse of the heart can be felt, sometimes seen.

The rhythmic contraction of the heart may be felt by placing the hand about its own width from the center line of the chest, at the level of the fifth interspace. If the breasts are not pendulous, about ½ inch below the nipple on the left side.

The Heart Sounds.—The sounds made by the heart may be represented by the syllables, *lubb-dup.* The "lubb" is prolonged and low pitched. "Dup" is quick, short, and high pitched. The rhythm they make is "lubb-dup," pause; "lubb-dup," pause; "lubb-dup," pause.

The first sound is supposed to be due to the muscular contraction plus the closing of the auriculo-ventricular valves. This is heard best at the apex of the heart (fifth interspace, from 3 to 3½ inches from the midsternal line), where the predominant valvular sound is that of the mitral valve. At the fourth interspace on the right edge of the sternum, the sound of the tricuspid valve is most clear.

The second sound is due to the closing of the aortic and pulmonary valves. They are heard best at the base of the heart, at the level of the second rib. A ridge on the sternum, marking the articulation of the manubrium and gladiolus serves as a landmark for locating the rib. At the right edge of the sternum the sound of the aortic valve is most pronounced. At the left edge the pulmonary valve is best heard.

The loudness of the sounds depends upon the vigor of the muscular contraction, and the force with which the valves close. Another element is the thickness of the chest walls. A wall covered thick with fat makes the sounds almost inaudible.

The Output of the Heart.—There must be as much blood leaving the heart as passes out from the arterioles into the capillaries. Unless the blood stagnates at the periphery, a like amount is brought back through the veins. A fair average would be an output of about 60 cc. at each contraction of the heart. In general, the greater the amount of blood received by the ventricles, the stronger is their contraction, and the less frequent. Quickened heart action usually means a smaller output each time. This is not invariably the case, however, as under the influence of adrenalin, the rate and output are both increased at the same time.

The Work Done by the Heart.—By taking the average blood-pressure at the aorta, the amount of blood sent out at each contraction, and the velocity with which it is expelled, the amount of work done by the heart may be estimated in terms of gram-meters. For a man at rest, it has been calculated to equal 100 gram-meters at each contraction. This is equivalent to 10,000 kilogram-meters in twenty-four hours. For one doing hard muscular work, the figures are much greater. For the supreme effort that an athlete may make, the work may be equivalent to 450 gram-meters per heart beat, or 81 kilogram-meters in a minute. It is only by a gradual building-up of the heart muscle that such excessive demands upon a heart may be safely met.

It is evident that the heart is able to adapt itself to an increasing amount of work. The increase may be due to either more blood brought to the ventricle, or to more resistance offered at the aortic orifice. The heart muscle must force the blood into the aorta against the pressure in the arteries. It must impart velocity to the stream, increasing as the heart rate quickens. The higher the arterial resistance, the more the muscle of the heart must contract to raise the pressure in the ventricle above that in the arteries, so the aortic valve can be forced open to allow the egress of the blood. An increased amount of blood coming into the ventricles will distend them, so stretching the cardiac muscle. As in the skeletal muscles, within limits, the more a muscle is stretched, the more strongly it contracts. The cardiac muscle acts in this way—the cavity of the ventricle enlarges, the fibers lengthen, and the work done increases. This is the method by which the heart of the athlete grows larger and stronger. This is the method by which a "leaky" heart compensates for its defect. However, hypertrophy cannot go on indefinitely. The muscle fibers become stretched until they are so thin, the physiological cross-section is lessened, and the power to work declines. At this stage a "dilated" heart means a weak, tired heart.

The rate of the heart is increased by higher temperatures, and decreased by lower temperatures. More efficient work is done at the slower tempo.

Changes in the carbon dioxide content of the blood alters the amount of work done. Increased amounts in the blood lessen the power of the heart. Superoxygenation, to a moderate degree, increases power. Acid condition of the blood, whether from increase in the lactic or other acid, or decrease of the alkaline reserve, acts to lessen the power of the heart.

Steadying the Output of the Heart.—The blood leaves the heart in spurts, going into the aorta and pulmonary artery, but in the smallest arteries and capillaries the flow is steady, without any waves. This change is due to "arterial recoil" and "peripheral resistance."

Arterial Recoil.—The aorta contains much elastic tissue, so that as the blood is thrown into it at each ventricular systole it is easily distended. When this impulse is over, the walls recoil, pressing down upon the blood, and imparting a steady push to it. As the aortic valve is closed, the blood cannot go back to the heart, and must go toward the periphery. The larger arteries contain a great amount of elastic tissue, so this pressure of the walls continues for some distance from the heart, making the flow more steady. This pressure upon the blood in the arteries is called *arterial tension.* It is subject to various influences which increase or decrease it.

The wave induced by the heart's systole is lost in the small arteries, and in the capillaries, so there the flow is steady and slow. As the blood goes out into the "arterial tree," there is more resistance to its onward flow, due to the narrowing of the tube. This is *peripheral resistance,* which is increased or lessened by muscular contraction or relaxation. The greater the resistance, the harder the heart has to pump to send the blood to its destination, with consequent increase in arterial tension. Arterial tension or *blood-pressure* represents the pressure against the sides of the bloodvessels exerted by the moving blood. This pressure distends the walls of the bloodvessels, so that any cut across an artery is followed by a vigorous spurt of blood. The amount of pressure varies in different parts of the cardiac cycle, highest during systole, lowest during diastole.

The systolic pressure represents the *force* of the heart beat mainly, while the diastolic represents the load sustained by the walls of the arteries. If there was no arterial recoil the diastolic pressure would be about zero. If peripheral resistance is increased, and the rate of the heart is diminished, the diastolic pressure is high. With the diastolic pressure low and the heart-rate increased, peripheral resistance is probably less. The higher, and more persistently high, the diastolic pressure is, the greater the strain on the heart and arteries. Average systolic pressures are 150 mm. Hg., with diastolic pressure of 80 to 90.

Some other factors that increase tension or blood-pressure are standing, walking or running, as compared with sitting or lying; mental strain and very hearty meals. Cold baths increase, while full tepid baths decrease the pressure. Strong emotions increase the pressure. Habitual muscular tension, definitely increases the blood-pressure, while neuromuscular relaxation lessens a high pressure.

The pressure during systole is lowest in children, gradually increasing as the years advance until it becomes relatively high in the aged. Whether this is due to a gradual hardening of the artery walls is open to discussion, as the less elastic these walls are the greater is the rise in systolic pressure with every heart beat. But, as high blood-pressure occurs in early middle life in some cases,

there are evidently many causes still unknown. The secretion of some of the ductless glands is, one way or another, a potent influence. The pressure in the veins is usually zero or even negative, as the force of the heart's contraction is lost in the capillaries.

The Velocity of the Blood Stream.—A stream confined between high, narrow walls runs more rapidly than when the bed widens as the stream spreads out over a meadow. So—the rate of flow in the large arteries is much greater than in the arterioles and capillaries, which by their number make a wider bed.

The Pulse.—Although the blood flow in the large arteries is changed from a series of spurts to a steady stream, there is added to this stream, at each heart beat, an extra force. This is a wave which starts from the aorta and is continued through the arterial system, gradually becoming less marked. It is lost in the arterioles and capillaries. The wave is called the *pulse.*

At the carotid artery in the neck, the pulse is practically synchronous with the apex beat. It is somewhat later at the radial artery in the wrist—still later in the arteries of the foot.

The radial pulse is usually just internal to the styloid process of the radius, varying in location in different individuals. It is customary to "feel the pulse" at this point. By it is indicated the rate and regularity of the heart rhythm; the strength; the fulness of the stream, and the condition of the arterial walls.

Various mechanisms are used to record a graphic representation of the pulse. These show a wide variation between conditions at the subclavian, carotid, brachial, radial, and femoral arteries. There is always a primary upward wave resulting from the entrance into the aorta of the blood, followed by a declining line, broken by another upward wave, which is called the "dicrotic wave." This is a reflected wave from the peripheral resistance. The greater the resistance the less marked the dicrotic wave.

Venous Pulse.—This is sometimes developed in the internal jugular vein. On account of the firm or bony walls of the cranial veins being pressed upon to take up the force of the arterial blood, the pulse wave is transmitted, as through rigid tubes, into the jugular veins.

The Venous Suction Pump.—So little force has the blood in the capillaries, or in the neighborhood of the ultimate tissue cell, it would simply stay there indefinitely, unless some force could carry it along. (This is illustrated in the swelling of the hand from retained lymph, if the arm is in a splint. The lack of use of the hand and arm prevents the onward flow of the lymph. When muscular function is resumed the swelling disappears.) The force pump has lost its effect, but a suction pump is now developed which returns the venous blood to the heart. It is developed by the respiratory movements, the changing size of the heart, muscular

contractions, and joint movements. During inspiration, the diameters of the chest increase, producing a potential vacuum. This sucks the air into the lungs from outside, and sucks the blood into the chest and heart from other parts of the body. The blood so drawn in must be venous, as the strong action of the heart sends the arterial blood in the opposite direction. The inspiratory movement also draws the lymph from the periphery, as the lymph vessels are connected with the venous system.

A considerable amount of suction is exerted by the relaxation of the heart, drawing the blood from the venæ cavæ and pulmonary veins into the auricles.

There are many opportunities for the development of vacuums in the veins, as the blood is in this system of closed tubes. If a vein is pressed upon, the walls collapse, the blood is forced from under the pressure, and when the pressure is removed, a vacuum results. The blood that was pressed out has had but one direction in which it could go, that is, forward, as the valves prevent its backward movement. The blood must rush forward to fill the vacuum, so the net result of the pressure on the vein is to carry the venous blood toward the heart. Every muscular contraction, with the broadening of the muscle produces pressure on the vessels contained in its substance, with resulting suction. A part of the body in which the muscles are not used becomes, as it were, "water-logged," having nothing to start the venous blood and lymph toward the heart. A majority of the ills of the body are accompanied by, possibly some are caused by, the sluggishness of the venous flow. The rate at which one lives is well measured by the activity of this side of the circulation. By reason of the attachment of the deep fascia to the large veins at the joints, movement of the latter pulls upon the veins, and increases suction.

By these means, the force pump on the arteries, and the suction pumps on the veins and lymphatics, the blood gets around the body, making a complete circuit every twenty-two seconds.

Quantity of Blood in Body.—The quantity of blood is about 9 per cent of the body weight. This approximates 13 pints in an average man. It is not enough to furnish every part with a full supply all the time. If the muscles and skin have plenty, there is not sufficient for the digestion of a hearty meal, or to allow much effective brain work.

Approximately one-fourth of the blood is distributed to the liver, another fourth to the skeletal muscles, the third fourth to the heart and large bloodvessels, while the rest of the body has the last quarter.

Fortunately, the glandular organs have alternating periods of work and rest. When they work, they require a large supply of blood, which goes to them through the vasomotor nerves acting in

harmony with the secretory nerves of the autonomic system. These organs are usually supplied by the lesser-sized arteries that have considerable muscle tissue in their walls. Their caliber is readily decreased by the *vasoconstrictors* or increased by the *vasodilators,* thus lessening or increasing the blood supply. When the muscles are in vigorous contraction, much blood is needed by them and by the skin, and their demand is more insistent than that of even the digestive organs. The process of digestion may be suspended by hard muscular work soon after eating.

The Nerve Supply to the Heart.—The cardiac muscle has a method of contraction that differs from that of the voluntary or involuntary muscles. This is a rhythmic action that, after the nerve supply through the general nervous system is cut off, is maintained independently. The contraction runs through the heart from base to apex in a wave, synchronous on both sides. It has been thought that the rhythmic contraction is due to intrinsic sympathetic ganglion cells which send motor impulses through their axones to the muscle cells. Some parts of the heart, as the upper portion, have many of these cells and contract very strongly. The apex has few and its contraction is weak. Another theory is that the contractions originate in the muscle cells by reason of the chemical stimulation of the surrounding fluid. By experiment it is found that the heart of a cold-blooded animal can be removed from the body, and be made to continue its contraction for a long time, by placing it in a solution of certain salts. This, without any external stimulus. This seems to imply a response to chemical stimuli of the muscle cells without regard to nerves. The fact remains, however difficult it is to explain, that the heart muscle possesses some power of independent action within itself.

While the heart may continue to beat automatically by means of these intrinsic ganglia or chemical reactions, there must be provision for adjusting the rate to the varying needs of the body.

Starling describes an experiment with a dog in whom the fibers connecting the heart with the central nervous system had been cut. The dog lived eight months in fairly good health, with his weight remaining normal. But he was incapable of any running, as the heart could not respond by increasing its rate of contraction to meet the increased demand for blood.

The nerves governing the heart come from the medulla, through the *vagus,* and from the lower cervical and upper dorsal region of the spinal cord, in connection with the sympathetics.

The vagus is an inhibitory nerve whose efferent fibers act chiefly on the auricles of the heart, to slow its rhythm. Since the auricles supply the blood to the ventricles, this effect is transmitted to the ventricles, although they recover from its influence after a short time. If sufficient stimulus is given to the vagus, the action of the

heart may be stopped, so that no beat occurs. The ventricles may begin to beat again without the auricles first contracting, or the latter may beat later in the cycle. This slowing of the rate allows more time for the ventricles to be filled from the auricles with a consequent stronger contraction. This action of the vagus may be called a tonic effect, which, according to Abrams, includes all the involuntary muscle fibers in the bloodvessels and viscera.

The efferent fibers of the sympathetic nerves of the heart have an effect exactly opposite to that of the vagus. The rate of contraction is increased by shortening the diastolic period. The heart beat is accelerated in rate and augmented in strength, thus producing a tonic effect. In this the action is similar to that of the hormone "adrenalin," which produces acceleration and augmentation, with an increase in the oxygen intake.

Ordinarily, the rhythm of the heart is regulated by the balanced action of both vagus and sympathetic.

Various influences modify the action of these two groups of nerve fibers. From the psychic centers emotions may change the heart rhythm; muscular activity and the standing position increase it, while age, food, variation in blood-pressure, etc., will have their varying effects. Increase of thyroid secretion in the blood increases the heart-rate and blood-pressure. Febrile conditions are accompanied by increased rate.

Reflexes of the Heart.—From the heart, large bloodvessels, the higher brain centers, and through chemical changes in the blood, afferent fibers carry messages to the centers in the medulla. Here is initiated activity from both inhibitory and accelerator centers, by which the reflex slowing of the heart, its increased rapidity, the raising of the blood-pressure through constriction of the splanchnic area, the lowering of it by the dilatation of the arterioles, or the production of reflex movements are achieved.

When the aorta is much distended from high blood-pressure, a *depressor* nerve carries the message to medullary centers which respond by slowing the heart rate and lowering the blood-pressure. This last may be through the general dilatation of the bloodvessels, especially those of the splanchnic area. Excessive strain on the heart is averted by this mechanism.

It is thought that there are no nerves of ordinary sensation in the heart. Painful impressions, such as those of angina pectoris, may arise from the heart, but they are referred to the chest wall and the arm.

When the heart has extra work to do the sympathetic fibers dilate the coronary arteries of the heart, so providing more oxygen for its use.

The Vasomotor Nerves.—The various organs and parts of the body require more or less blood supplied to them accordingly as

they are active or at rest. When the organs concerned with some one function require an extra amount of blood for their activity, other organs, then resting, give up much of their blood supply. This variation in quantity supplied is effected by means of the vasomotor nerves. They cause the constriction of the caliber of the arteries by stimulating the circular muscle fibers to contract. By allowing the fibers to relax, the artery dilates. These nerves which regulate the size of the smaller arteries are derived from the cells in the lateral horns of the gray matter of the spinal cord, from the second thoracic to the third lumbar segments. The controlling center for the nerves is in the medulla, and is known as the "vasomotor center." To this center go afferent impulses from the higher centers of the brain, and from all other parts of the body. These produce a reflex through efferent fibers which maintains a certain "tonus" in the arteries.

In addition to this medullary center, there are centers in the spinal cord.

The fibers come out of the cord in company with the anterior motor roots of the spinal nerves, receive a medullary coat and sheath, and are the white rami communicantes or preganglionic fibers of the autonomic nerves. They pass into the vertebral ganglia and arborize around their cells. From the cells gray fibers pass out, which join spinal nerve trunks, going in them to the walls of the bloodvessels in the skin, head, face, neck, the trunk, the upper and lower extremities, and the abdominal viscera. The distribution is to the circular fibers which are either stimulated to contract and so lessen the amount of blood going through—or their contraction is inhibited, so that more blood passes through the artery. The first set are called *constrictors*, the second set are *dilators*.

The most important of the constrictor vasomotor nerves is called the *splanchnic* nerve. It is derived from the lower seven dorsal with the upper two lumbar roots. They pass into the semilunar ganglion of the solar plexus. From here the fibers pass to the vessels in the abdomen. If this nerve is cut, allowing the abdominal vessels to fill with blood, the general blood-pressure is lowered. It is possible that the splanchnic nerve may also carry dilator fibers.

This alternation of full blood supply to the different parts keeps the blood on the move and improves its quality.

The Regeneration of the Blood.—As the blood is constantly receiving waste products, and having its nutritive materials used, it would soon deteriorate if there were no provision for its regeneration. Every secretion that goes into the blood alters its character. That which leaves the adrenal glands is different from the blood that entered. This is true in the case of every gland, whether something is taken out or put in. The suspension of the function of any one

gland has an immediate effect upon the composition of the blood, deranging its balance. Sluggishness of the blood which should go to the liver *via* the portal system results in the accumulation of wastes in the blood. By means of the liver and kidneys, the blood is said to be purified. Through the lungs O is brought in and CO_2 taken out. Red cells are replenished by the red marrow and the spleen. Deleterious bacteria are strained out by the lymph glands which also supply additional white corpuscles. Any one of these provisions failing, the blood suffers—with it the whole organization. A vigorous flow, affording opportunity for rapid exchanges of its elements is necessary to maintain the balanced composition of the blood—to regenerate it.

The Work of the Lymph.—The lymph vessels contain lymph, a colorless fluid which is the plasma of the blood after it has leaked through the walls of the capillaries into the spaces surrounding the tissue cells, plus the material coming from the cells. Properly speaking, this is *tissue fluid,* which on being taken up by the lymphatic vessels becomes *lymph.* This material includes all kinds of secretions as well as waste. After the cells have taken what they need this fluid must go back into the bloodvessels. The venous capillaries cannot take it all up, so the open stomata of the lymph radicles must do it. Physiologists are not agreed as to just how this is done, but it is done, and the surplus lymph goes through the lymphatics to the venous system. Opinions differ as to how much is due to the osmotic pressure—how much to the secretive activity of the endothelial cells. If the blood-pressure increases, there is apt to be greater pressure of the fluid to get out of the capillaries into the spaces. During inaction there is little flow, but when the venous suction pumps pull the flow becomes active. The peristaltic action of the muscles of the intestine moves the lymph in that region.

The *lymph nodes* serve to strain out of the lymph certain deleterious substances. In them the white corpuscles, or at least, some of them, seem to originate.

The Work of the Red Corpuscles.—Some of the red corpuscles are formed in the red marrow of the bones, but it is open to question if that is the only source for their production. The spleen appears to be a reservoir for red corpuscles, which are driven into the circulation by the contraction of the spleen.

Their chief constituent is hemoglobin, which gives the red color to the blood. It is a form of organic iron, which has a strong affinity for oxygen. In the lungs the hemoglobin takes oxygen from the air and carries it in the blood stream to the tissues. The cells take it and by a process of oxidation use it, producing some form of energy and carbon dioxide. The latter is carried by either the red corpuscles or plasma to the lungs to be eliminated.

The Work of the White Corpuscles.—This has been the subject of much investigation. All white corpuscles are not alike. The two main groups are leukocytes and lymphocytes. The leukocytes wander about, but the lymphocytes seem unable to do so. It is probable the white corpuscles protect the body from pathogenic bacteria and other foreign organisms. The formation of substances in the blood which immunize the body to infection is thought to be the work of the white corpuscles. The prevention of the entrance of harmful microörganisms is largely through the skin and mucous membranes. After they gain entrance their destruction must be accomplished by phagocytosis.

The white corpuscles aid in the absorption of fats and peptones from the intestines. They may take some part in the coagulation of the blood, and help maintain the normal supply of proteins in the blood.

The Blood as a Carrier.—The plasma is involved in serving as a common carrier between the various parts of the body. Among the substances carried are oxygen, carbon dioxide, water, nitrogen, various proteins as fibrinogen, paraglobulin, and serum albumin. Substances called extractives, as fats, sugars, urea, uric acid, creatin, jecorin, glycuronic acid, lecithin, cholesterin and lactic acid are also present. The mineral salts, include combinations of chlorine, carbon, sulphur and phosphorus with sodium, potassium, magnesium and iron. And, yet more. Enzymes, the internal secretions, immune bodies, complements and opsonins, and prothrombin and antithrombin. With such a complex organization, the plasma gives up different substances to different cells and receives a supply of other material to carry around, either to be used by other cells, expelled from the body as waste or used to stimulate the functions of other parts.

Coagulation of the Blood, or Clotting.—Unless there is some injury or disease of the bloodvessels, while the blood remains in them, it is fluid. If the vessels are cut, so the blood escapes, there is formed a solid plug or clot at the open ends, which sooner or later stops the bleeding. This coagulation of the blood is produced by a network of *fibrin,* in which the corpuscles are caught. Fibrin does not exist in the blood while it is in the vessels, but develops from such substances as thrombin, fibrinogen, the platelets, possibly, the white corpuscles, when the blood escapes. If these antecedents of fibrin are lacking in the blood coagulation does not take place, and bleeding may continue indefinitely after it begins. The condition is known as "hemophilia," and its subjects as "hemophiliacs," or "bleeders." If the wall of a vein is injured, platelets form a coagulum over the spot, which in normal health will soon be covered with endothelium, so restoring that portion of the vein to its normal condition.

QUESTIONS.

Describe the heart, and make a diagram of it.

Compare the structure of an artery and a vein with reference to the work done by each.

What is the relation of capillaries to cells?

How do lymphatics begin?

Why should two sets of vessels be needed to return blood to the heart, when one set is sufficient to carry it from the heart?

What is the pulmonary circulation?

What is the portal circulation?

Trace the course followed by a red corpuscle in going from the right auricle to the palm of the left hand, naming the arteries in order.

Trace the course going from the left ventricle to the right kidney.

What parts of the body are drained by the inferior vena cava?

What area is drained by the long saphenous vein?

What area is drained by the portal vein? By the hepatic vein? By the internal jugular vein?

Describe the thoracic duct.

What is the "cardiac cycle?"

How is the intermittent flow of blood from the heart changed to the steady flow, with waves, in the arteries?

What work is done by the blood plasma?

What work is done by the red corpuscles?

What work is done by the white corpuscles?

What is "arterial tension?"

How does the blood get back to the heart from the capillaries?

By what means is the supply of blood to various organs regulated?

What value has dilatation of the vessels of the splanchnic area?

CHAPTER X.

THE RESPIRATORY SYSTEM.

Respiration may be defined as an exchange of gases, of which the object is to provide oxygen for the combustion in the tissues, and to remove the products of combustion in the form of carbon dioxide. As with other vital processes of the body, the essential action of respiration takes place in the microscopic tissues.

The process may be divided into two parts, *external respiration*, during which the air external to the body is carried to the lungs. The exchange occurs between the blood in the capillaries of the pulmonary arteries and the air in the alveoli. *Internal respiration* occurs in the ultimate tissues, with the exchange between the blood in the systemic capillaries and the contents of the tissue cells.

THE ORGANS CONCERNED IN RESPIRATION.

The passages through which the air passes to the microscopic tissue cells, in their order, are:

Anterior nares of nose (mouth).
Posterior nares (naso-pharynx).
Pharynx.
Larynx.
Trachea.
Bronchi.
Bronchioles.
Alveoli.

The Nose.—The nose is a prominent feature of the face, and varies in shape according to the race and the climatic conditions under which the race has developed. Tropical races have rather flat noses, with short air passages, while races living in colder regions develop longer air passages with more prominence of the nose. The nasal bones are short and small, forming the "bridge of the nose," and to them is attached a cartilaginous addition that provides for movement of the nostrils and takes up the force of external blows to a considerable extent. Small muscles are attached to the nose providing for facial expression, and for extra efforts in breathing.

The nose is lined with mucous membrane containing many "goblet cells," and having a rich blood supply. This membrane does not cover the small surface only that is visible on cursory inspection, but is continued over a large area by covering the "tur-

binated bodies." These are three in number, on each side, and their convoluted shape gives a large area of warm mucous membrane over which the air passes on entering the nose. The air can thus be warmed before it reaches the more delicate structures beyond.[1] The area on the superior turbinated occupied by the nerve of smell (olfactory) has few, if any, goblet cells. The air entering the nose through the anterior openings does not pass as high as this area, but takes a more direct way from front to back.

The Posterior Nares.—Through the posterior openings of the nose, the way leads into the naso-pharynx, on the posterior wall of which is a mass of adenoid tissue. When this tissue becomes hypertrophied, the condition known as "adenoids" develops, causing interference with the easy ingress of air, and consequent normal development of the child. (Figs. 237 and 238.)

The Pharynx.—The pharynx is the space at the back of the mouth, and is divided into the nasopharynx above, opposite the posterior nares, the oropharynx, opposite the tongue, and the laryngopharynx, just above the larynx. It is 5 inches long; on the posterior wall are two openings which are the beginnings of the Eustachian tubes which carry air to the middle ear. It is lined with a continuation of the mucous membrane of the nose, mouth, middle ear, and larynx, but ciliated epithelium to the level of the hard palate provides for the waving outward of mucus and its easy removal. On the outside of the pharynx are a number of muscles that constrict its caliber, forcing the bolus of food, after mastication, from the mouth into the esophagus.

The Larynx.—Opening from below the pharynx, are two apertures, the esophagus and the larynx. Except during the act of swallowing, both are open at all times. When a bolus of food passes into the esophagus, a trap-door closes over the larynx to prevent food going into it. This door is the *epiglottis.* (Fig. 269.)

The Epiglottis.—The epiglottis is a thin triangular leaf-like piece of cartilage, attached to the base of the tongue, and to the upper and anterior part of the larynx. Its action is involuntary, but when the coördination of the muscles of the pharynx and those attached to the epiglottis becomes impaired, it may fail to close over the larynx, allowing food to enter the latter. This will cause choking, and violent efforts at coughing it out. If the material enters the trachea it may entirely block the ingress of air.

The appearance of the larynx is that of an irregular box made of four pieces of cartilage, with the muscles and ligaments that hold them together. The cartilage keeps the lumen open. The muscles on the outside are concerned in swallowing, respiration, and phonation. Over this box-like structure, at the upper end, pass two

[1] Under the description of the nerve of smell, additional details are given of the nose.

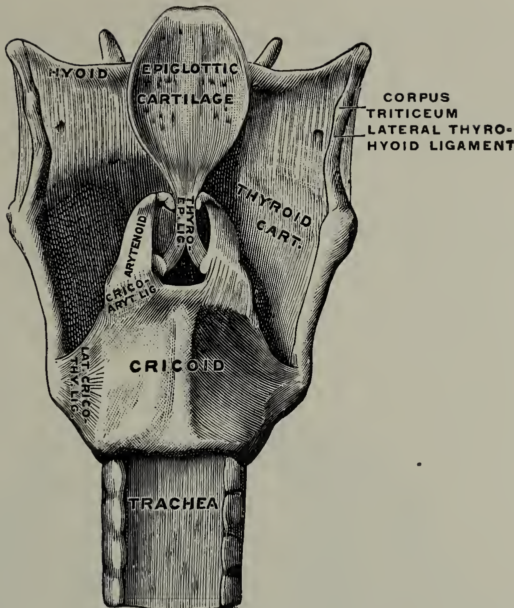

Fig. 269.—Laryngeal cartilages and ligaments from behind. (Testut.)

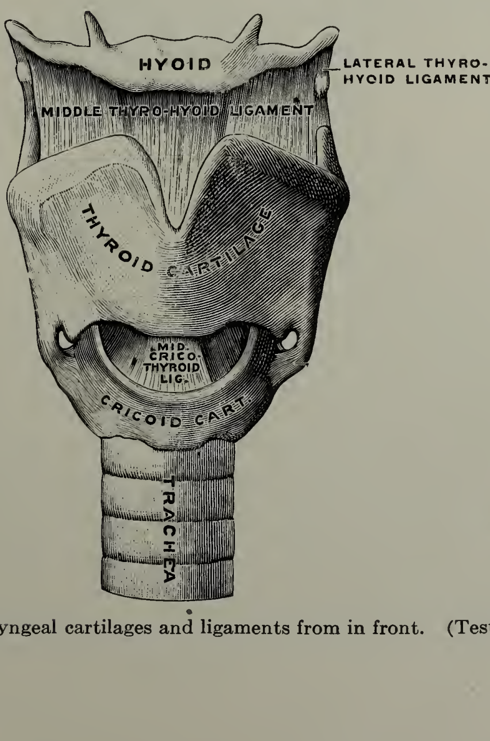

Fig. 270.—Laryngeal cartilages and ligaments from in front. (Testut.)

bands of fibrous tissue, covered with mucous membrane. These are the *vocal cords*. They are so placed as to leave a triangular opening which varies in width or which may be entirely closed. This opening is the *glottis*. The variation of size provides for the passage of more or less air, according to circumstances. The air coming from the lungs sets the vocal cords in vibration, causing sound.

The glottis may be closed at the end of inspiration to prevent the expiration of air and give fixation of the diaphragm in connection with the muscles of the abdominal wall to produce compression of the viscera below, as in defecation, micturition, parturition, and vomiting. It may also be closed to fix the chest and give greater

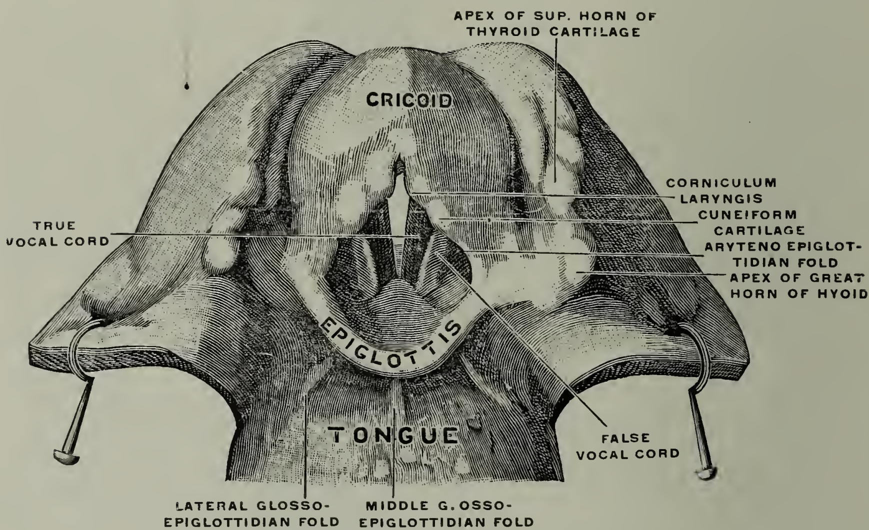

Fig. 271.—Larynx, viewed from above. (Testut.)

power in muscular efforts, such as lifting, jumping, etc. An additional effect is interference with the flow in the veins draining the brain. It is to be noted that by the voluntary closing of the glottis at the *beginning* of inspiration, the suction effects of the inspiratory movements can be increased.

The Trachea. (Fig. 272.)—The trachea is the next part of the respiratory tract, consisting of a tube about 4½ inches long, made of fibrous tissue in which is imbedded incomplete cartilaginous rings whose function is to keep the tube patulous. The back of the trachea lies in contact with the esophagus. That the passage of food may not be impeded, the cartilaginous rings are lacking in that situation.

The Bronchi.—The trachea divides into two branches called the *primary bronchi*, that go to the right and to the left into the lungs.

These are large tubes with cartilaginous rings throughout their circumference, lined with a mucous membrane continuous with that of the larynx. The bronchi divide into smaller tubes (bronchial tubes) which continue dividing and subdividing until the diameter becomes very minute. The cartilage in the walls continues until the tubes become as small as $\frac{1}{50}$ inch in diameter. These tiny tubes are the *bronchioles*. They vary in diameter between $\frac{1}{120}$ and $\frac{1}{50}$ inch. Throughout these air passages ciliated epithelium is present.

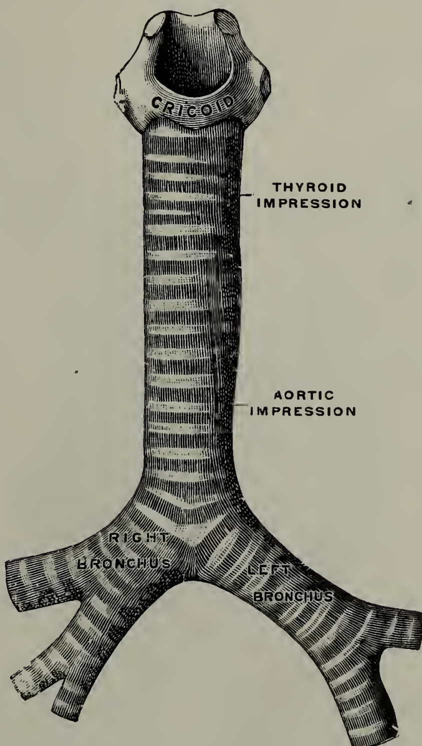

FIG. 272.—Trachea and bronchi, front view. (Testut.)

Alveoli.—Each bronchiole opens into a collection of 8 to 16 alveoli, or air vesicles, called a lobulette. It is here the actual work of external respiration occurs. The alveoli are from $\frac{1}{70}$ to $\frac{1}{200}$ of an inch in diameter, with walls of a single layer of flat epithelial cells with elastic fibrous tissue. The area covered by their walls is estimated at 90 square meters, or more than a hundred times the area of the skin of the body. Ramifying among the vesicles are the capillaries of the pulmonary arteries.

In these microscopic tissues are the two single layers of epithelial cells through which gases may pass freely, according to the amount of pressure exerted by each gas.

The Lungs.—The ramifications of the tubes with the alveoli and the areolar tissue holding them together constitute the *lungs.*

In shape they are two irregular cones, contained in the thorax, with the bases resting on the diaphragm, and the apices reaching into the neck about $1\frac{1}{2}$ inches above the clavicles. (Fig. 273.)

The lungs are covered by a sheet of serous membrane, the visceral layer of the *pleura.* This layer is reflected upon the chest wall, lining it. This forms the parietal layer of the pleura, which ordinarily is in contact with the visceral layer. A small amount of fluid is secreted to lubricate the surfaces.

The right lung is divided into three lobes, the left lung into two lobes. Each lobe is divided into a number of small areas, $\frac{1}{4}$ of an inch in diameter, called *lobules,* and these are collections of lobulettes. (Fig. 274.)

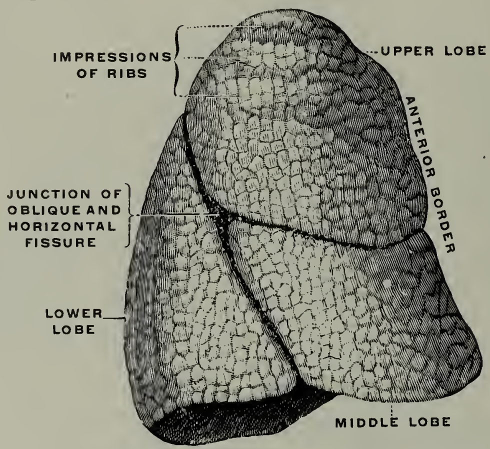

Fig. 273.—Right lung, outer surface. (Testut.)

The lungs are always close to the inner wall of the chest, and their shape changes with changes in the diameters of the thorax. Conversely, changes in the shape of the lungs produces changes in the diameters of the thorax.

The Mediastinum.—The mediastinum separates the two lungs, and includes all the space in the thorax not occupied by the lungs. It extends from the sternum to the spinal column, and from the upper opening of the thoracic cage to the diaphragm. Four divisions are made, the superior, anterior, posterior, and middle mediastinum. The superior is above the pericardial sac; the anterior in front of the same; the posterior behind, and the middle is occupied by the pericardial sac and its contents, the heart, with the beginning of the large bloodvessels.

In the superior and posterior mediastinums are important organs, as the trachea, esophagus, thoracic duct, vagus, and other nerves

FIG. 274.—Diagram of a lobule of the lung. A bronchiole is seen dividing into two branches, one of which runs upward and ends in the lobule. In the lobule are four groups of infundibula. At the left are two infundibula the alveoli of which present their outer surfaces. Next are three infundibula in vertical section, the alveoli of each opening into the common passageway. Upon the ultimate bronchiole of this group are alveoli. In the next group the first infundibulum shows a pulmonary arteriole surrounding the opening of each alveolus, and the second gives the same with the addition of the close capillary network in the wall of each alveolus. The same arrangement of vessels is seen in the alveolus upon the bronchiole of this group. Around the fourth group is a deep deposit of pigment, such as occurs in old age, and in the lungs of those who inhale coal-dust and the like. On the bronchiole lies a branch of the pulmonary artery (blue), bringing blood to the infundibula for aëration. It also supplies nourishing blood to the tubes and other structures within the lobule. Beginning between the infundibula are the radicles of the pulmonary vein (red), a root of which lies upon the bronchiole. The bronchial artery is shown as a small vessel bringing nutrient blood to the bronchiole (outside of the lobule), the artery and vein, and all of the structures between and around the lobule. No attempt is made to show the sustentacular tissue which occupies the spaces within and around the lobule. (Gerrish.)

and the great vessels connected with the heart. The heart encroaches on the space occupied by the left lung.

The Thorax.—The thorax is a cone-shaped cage, partly bony, partly cartilaginous and partly muscular, which contains the two lungs, the heart, the large bloodvessels, the esophagus, thoracic duct, various nerves, and glands. (Fig. 275.)

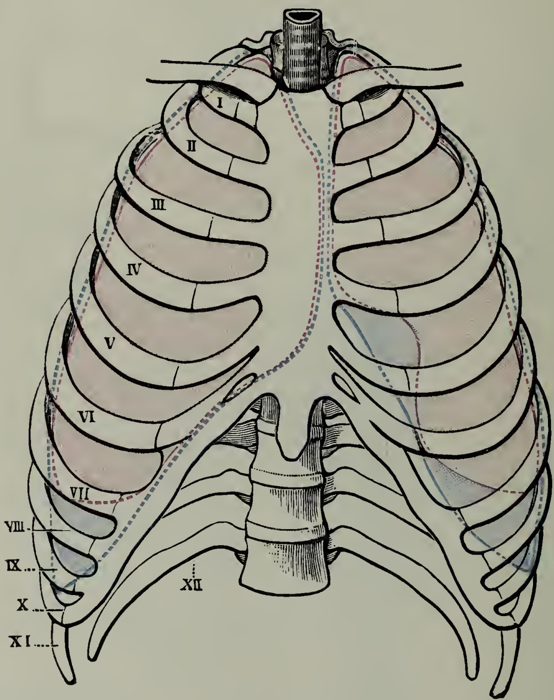

FIG. 275.—Relations of lungs (red) and pleuræ (blue) to the front walls of chest. (Testut.)

The cavity of the thorax is closed, and shut off from the abdominal cavity as well as from the outside, but the interior of the lungs communicates with the outside air by means of the trachea, etc. The atmospheric pressure, thus affects the interior of the lungs, but the walls of the chest prevent it from influencing the outside of the lungs. If the chest is punctured, the lungs immediately collapse on account of the equalization of the pressure outside and within.

When the air enters the lungs, the expansion produced causes them to fill the entire cavity, except where there are other structures. When air leaves the lungs, the chest walls follow the shrinking lungs. The thoracic cavity is made smaller, but the lungs still completely fill it. There is no permanently vacant space in either case.

Normal Position of the Thorax.—The position of the thorax

changes continuously during life, but the position at the end of a passive expiration may be considered essentially normal, and forming a starting point from which to estimate the degree of inspiration and expiration. Any enlargement of the thorax from this norm may be considered an active inspiration. Any diminution of the size may be considered an active expiration. A return to the norm after an active inspiration, is a passive expiration and is not caused by muscular effort but by the recoil of the lung tissue after expansion.

THE PHYSIOLOGY OF RESPIRATION.

The Beginning of Respiration.—Respiration is initiated in a newborn child as a reflex from the contact of its skin with the air, and is accompanied by its first cry. The vital functions of respiration and circulation begin in this way.

The Respiratory Movements.—Respiration may be said to begin with the movement of inspiration, in which the diaphragm contracts, increasing the diameter of the thorax from above downward. At the same time, the lower ribs are pushed outward, unless the inspiration is forced, in which case they tend to be drawn inward. It is possible the quadratus lumborum and serratus posticus inferior muscles hold the lower ribs from being drawn inward during inspiration. At the same time that the diaphragm is contracting, the scaleni and the external intercostal muscles contract and turn the ribs upward and outward, increasing the diameters of the thorax laterally and from before backward. In a living animal removal of the abdominal viscera allows the ribs to be drawn inward in inspiration. This indicates some support of the ribs by the abdominal viscera.

These changes in diameter would create a vacuum if the air did not rush in to fill the space. If the glottis is open it does fill the entire space so there is no room between the lungs and the chest walls. During inspiration the vocal cords separate, with the reverse of approximating to each other during expiration. The glottis may be closed voluntarily while the chest diameters are being enlarged, with an increase of the physiological effects of inspiration. (See Kellogg's *Treatise on Massage,* in connection with visceral lifting.)

When the diaphragm contracts, the central tendon descends about ½ inch, pressing upon the abdominal contents, so the abdominal wall bulges out. If the front wall of the abdomen is prevented from bulging, the pressure is transmitted downward, mainly to the pelvic cavity. Following the contraction of the diaphragm and other muscles, comes their relaxation, with an upward push of the dome of the diaphragm and a recoil of the lung tissue which pushes the air out of the lungs in expiration. The cavity of the thorax is decreased in all directions during expiration.

Under ordinary conditions, inspiration is active, expiration is passive. When inspiration is forced, to some degree, expiration becomes so.

Active inspiration and passive expiration is called *eupnea.* Forced or labored respiration is *dyspnea,* with the prefix of inspiratory and expiratory, according to whichever is forced. During forced respiration, all the muscles attached to the ribs, all that hold the scapula firm, and all that fix the abdomen may be called into activity.

Those called upon in forcible inspiration, in addition to the before-mentioned group, are the sternomastoid, the scaleni, pectoralis major and minor, trapezius, rhomboidii, and the serratus magnus. In forced expiration the muscles forming the wall of the abdomen—rectus abdominis, internal and external obliques, transversus, and the serratus posticus inferior, are called upon.

Stretching the spine upward influences respiration by increasing the thoracic diameters.

Under normal conditions it is said the internal intercostal muscles are active during expiration.

With the expansion of the lungs in inspiration, the bronchial tubes increase in length and width.

Types of Respiration.—These are distinguished according to the parts of the trunk that are especially involved. When the abdominal wall is pushed forward in inspiration, the breathing is called diaphragmatic, or abdominal. When the respiration is mainly carried on by the action of the ribs, increasing the lateral and anteroposterior diameters, with little movement of the diaphragm, it is called costal breathing. This variation can be produced by constriction of the waist as by tight belts or corsets. Abdominal respiration is likely to characterize all, even women, that have never worn tight clothing.

Ratio of Rate of Respiration, Pulse and Temperature.—The normal ratio between pulse and respiration is 4 to 1. With a normal temperature of 98.6° F. the pulse is 72, the respirations 18 per minute. With each increase of 1 degree in temperature, the pulse increases 10 beats, the respirations $2\frac{1}{2}$.

Inspiration and expiration follow each other with no interval between them, though on account of the passive nature of expiration it seems as though it were much shorter than inspiration, and followed by a pause. After every six to ten respirations there usually comes one that is distinctly deeper and longer. Ordinarily the depth of respiration varies with its rapidity, faster in shallow, slower in deep breathing.

Sounds of Respirations.—By applying the ear to the chest wall in different localities various respiratory sounds may be heard. Below the clavicle or over the scapula, with each inspiration a sound is

heard as of a gentle breeze in distant tree-tops. This sound is produced by the air going into the alveoli, and is called the "vesicular murmur." Listening over the middle of the back, the sound is higher pitched and as though one were blowing over the mouth of a bottle. This is caused by the passage of the inspired air passing through the bronchi. These are the two sounds possible in health. Various changes occur in disease, as bronchial respiration in vesicular areas; adventitious sounds, as râles, prolonged expiration, and irregularity in rhythm.

Relation of Respiration to Circulation.—While the exchange of oxygen and carbon dioxide is the outstanding fact in respiration, there are other very important features connected with it.

In the Chapter on the Circulation reference was made to the suction exerted on the venous blood by the action of the lungs. This is brought about by the difference between the pressures within the thorax, and that within the abdomen during respiration.

Intrathoracic and Intrapulmonary Pressure.—The space between the lungs and chest walls is practically *nil,* except during inspiration, but there is a space between the two lungs, the mediastinal space. The pressure exerted upon the contents of this space is the intrathoracic pressure, or it is the pressure exerted upon the heart, large vessels, thoracic duct, etc. The pressure in the interior of the lungs, which communicates with the atmosphere, or the intrapulmonary pressure, is that of the atmosphere.

During inspiration, when the thoracic cage increases in all its diameters, so that it is temporarily larger than the contained lungs, the intrapulmonary pressure falls temporarily below that of the atmosphere, or is *minus,* as the air becomes more or less rarefied, according to the amplitude and rapidity of the inspirations, and the size of the opening to the outside. At the end of inspiration if there is a pause, the pressure rises again to that of the outside atmosphere. During expiration, the collapse of the chest walls from the relaxation of the muscles of inspiration takes place rapidly enough to compress the air somewhat as it goes out, and a temporary rise of pressure occurs.

When the glottis is closed and a strong *inspiration* taken, the intrapulmonary pressure is much lowered, but if the glottis is closed and an *expiration* is made, the pressure is so much increased it may prevent the emptying of the venæ cavæ and pulmonary veins into the auricles. This effect may be observed in the appearance of congestion in the face and neck during violent coughing, straining at stool or supreme muscular efforts of any kind.

Under normal conditions the pressure upon the mediastinal space is negative or minus, for the walls of the thorax are interposed between that and the outside air. If the lungs are fully expanded they are a greater bar to the pressure of the atmosphere, and the

intrathoracic pressure becomes more largely a minus quantity than when the lungs are compressed in expiration. But, it is always negative.

Given, therefore, the outside atmospheric pressure exerted on the large veins in the neck and axilla through the skin, and the negative pressure in the mediastinal spaces, the venous blood is bound to go in the direction of the least resistance, that is, into the heart.

Intra-abdominal Pressure.—The pressure within the abdomen varies according to inspiration and expiration. In inspiration, the diaphragm presses down upon the abdominal viscera, the walls of the abdomen, *unless flaccid,* resist the outward pressure, with the net result of increased intra-abdominal pressure. This forces the blood from the inferior vena cava into the thoracic part of the vessel, where the pressure is negative. Thus the equivalent suction pump acts on the blood from the lower extremities, pelvic and abdominal regions.

The Relation of Respiration to Abdominal Functions.—The only action of the diaphragm is in inspiration, but that is rhythmic. Below the diaphragm are the stomach and intestines, in whose walls are smooth muscle tissue. The health of these organs depends upon their functional activity. This is directly aided by the respiratory movements of the diaphragm in exerting a massage action upon them. An intermittent pressure, which is the essence of massage, stimulates both the circulation and the peristaltic movements of the abdominal viscera.

If the respiration is mainly costal, this stimulation is lacking. The viscera are very apt to sag and function feebly.

It is necessary to emphasize the fact that while respiration does mean the exchange of O and CO_2 in the lungs, the effect produced upon the venous flow, and upon the activity of the abdominal organs, is sufficient reason for the use of respiratory exercises taken without marked changes in the normal rhythm of respiration. The use of "freak" methods of breathing is open to serious objection, as possibly interfering with the normal control through the medullary center. Respiratory exercises in themselves cannot increase the lung capacity. Increased demand for O in the tissues through increased muscular exercise does increase the lung capacity. One other point is the fact that given the enlargement of the thorax by the action of the respiratory muscles, it is unnecessary to violently draw the air in through the nostrils. It cannot be kept out of the lungs unless some obstruction to its ingress is presented. Any extra amount of inspired air is ineffectual in producing generally increased tissue respiration.

Pulmonary Capacity.—This indicates the total amount of air contained in the lungs, and is about 330 cubic inches, or 5000 cc.

Vital Capacity.—Vital capacity is the quantity of air that can be exhaled after making the largest possible inspiration. It can be measured by means of a spirometer, and though subject to error is fairly accurate as a means of testing one's available lung power. A spirometer consists of a graduated cylinder resting in a tank of water. The cylinder is counter-balanced by a weight which allows it to move with the least resistance up and down in the water. A tube passes from outside up into the cylinder chamber, through which the air is blown, so as to cause the cylinder to rise and indicate its amount.

The vital capacity of an average-sized individual is about 230 cubic inches, or 3700 cc. This amount is greater in tall persons, in those with very flexible chest walls, and where the occupation calls for vigorous respiration. When standing, the vital capacity is greatest. In prone lying it is least. The difference may be from 500 to 700 cc. in the average individual. Variations in the reading may be due to lack of understanding of the technique involved, inability of the subject to carry out instructions, or to defects in the instrument.

Residual Air.—It is impossible to expel all the air from the lungs, by any effort. That remaining is the residual air, about 600 to 1200 cc.

Tidal Air.—With each quiet respiration, there is a change of some 600 cc. This is the tidal air.

Complemental Air.—Complemental air is the amount that can be taken in by a forced inspiration. It is about 1500 cc.

Supplemental Air.—Supplemental air is the amount that can be forced out by effort and is about 1500 cc. These figures vary with exercise.

THE COMPOSITION OF INSPIRED AND EXPIRED AIR.

Atmospheric air in general consists of 20.96 volumes of oxygen, 79 of nitrogen, 0.04 of carbon dioxide, a variable amount of watery vapor, a small amount of organic material, ammonia, dust, nitric acid, etc.

It varies in temperature from 20° F, below zero to 115° F. above, in the temperate climes, with further extremes possible. Its temperature is modified by passing through the nostrils, so it is more nearly 70° F. when it arrives at the lower air passages.

Expired air has undergone certain changes. Oxygen is 16.02 volumes, nitrogen is 79, CO_2 is 4.38, and it is saturated with watery vapor at a temperature of 98.6° F.

There has been a decrease in oxygen of 4.94 and an increase of carbon dioxide of 4.34 volumes. More oxygen has been lost than shows in the carbon dioxide, but it is supposed some atoms of

oxygen have combined with hydrogen and formed water. Body heat is lost by this elimination of water after its conversion from a liquid to a gaseous state.

It does not seem possible to say just how much carbon dioxide is necessary to make air unfit to breathe. A proportion of 4 per cent in a confined place causes definite symptoms of distress, but a fairly good rule is to try to get out of air that, to one just coming from fresh open air, has an offensive smell.

THE EXCHANGE OF OXYGEN AND CARBON DIOXIDE.

There are three forces effecting the exchange of these elements.

1. The movements of inspiration and expiration.
2. The changing size of the heart.
3. The diffusibility of gases.

The first two forces result in the variation of intrapulmonic and intrathoracic pressure, which causes the alternate ingress of air rich in oxygen and the egress of air charged with CO_2. The diffusibility of gases effects the exchange in the alveoli, and in the microscopic cells of the body.

In a mixture of gases, each presses according to its volume. When oxygen has 21 volumes, it presses into the lungs with more force than when it has but 16 volumes, as in expired air.

If a membrane is interposed between two gases of different volumes, that with the higher pressure would go through until the pressure is equalized on both sides of the membrane.

In the lungs, this permeable membrane is the single layer of epithelial tissue in alveolar and capillary walls, and through this the oxygen is going from the outside. The red corpuscles load up with it. When the carbon dioxide arrives with a pressure of 4.38 it goes through the membrane because the CO_2 in the atmospheric air has less pressure, so the CO_2 passes out.

The arterial blood passes to the tissues nearly saturated with oxygen. In the systemic capillaries the pressure of O is much greater than is that in the cells, so it is given off to the cells. In the cells, CO_2 is constantly being formed and its pressure is higher than in the blood and lymph in the neighborhood. It therefore passes into the blood and is carried off.

As the blood goes through the capillaries CO_2 is given off from the cells. A small part is absorbed by the plasma, but most of it combines with sodium and potassium to form bicarbonates. The materials of which these are formed come from the hemoglobin. The greater part of the CO_2 is carried by the red cells in this combination. In the plasma there is a certain amount of bicarbonate of soda known as the "alkali reserve." As the hemoglobin gives up O to the tissues, its acidity lessens, so it is more ready to release

alkaline substances. The CO_2 goes to the lungs firmly combined as bicarbonates. In the lungs the hemoglobin taking up O becomes more acid, and this causes a breaking-down of the bicarbonates and the liberation of CO_2 to pass out of the lungs. When the "alkaline reserve" in the body is diminished appreciably, the elimination of CO_2 is lessened. Respiration is more superficial, while symptoms of "acidosis" may develop.

THE INNERVATION OF THE RESPIRATORY MOVEMENTS.

The diaphragm is supplied by the phrenic nerve, and branches of the cervical and brachial plexi supply the other muscles of inspiration, while branches of the lumbar plexus supply the abdominal wall. The facial nerve supplies the nose, and the vagus, the larynx. By the influence of the vagus, the varying needs for more or less O is regulated. Respirations occur without the vagus, but no increased need can be met. The muscles concerned are all voluntary, so respiration may be increased or decreased at will. But, the ordinary movements occur without conscious control through centers in the medulla. This center is apparently self-sufficient, and sends out the impulses that coördinate the muscles concerned. The rate is varied according to the needs of the organism. The normal rhythm of 15 to 18 per minute goes on, day and night, waking or sleeping. Muscular activity, emotions, sleep, and temperature vary the respiratory depth and rate.

It may be that the accumulation of carbon dioxide in the blood serves as the stimulus to the center in the medulla. The respiratory center is very sensitive to variations in the CO_2. The variations probably control the depth and rhythm of the respiratory movements. During vigorous muscular activity, the CO_2 is developed faster than the lungs can get rid of it. This causes an accumulation of CO_2 in the blood, which apparently stimulates the respiratory centers. The response is increase in the respiratory movements, with an increase in the amount of O taken in. In this way, increasing the tissue demand for O increases the lung capacity.

The tension of the O in the air at approximately the sea level is about 155 mm. of Hg. At 14,000 feet elevation this decreases to 89 mm. The higher the altitude, the less the O pressure. The needs of the body for O fail to be met at very high altitudes, resulting in severe headache, confused thinking, precordial distress, and nausea.

If one can withstand the immediate effects of high altitudes, there is compensation in the way of a relative increase of blood corpuscles, and a diminution of the plasma. The human mechanism can adapt itself, within limits, to life far above or far below sea-level.

QUESTIONS.

What is respiration and where does it take place?
What is the mediastinum?
What is "intrathoracic pressure?"
What is "intrapulmonary pressure?"
What are the boundaries of the lungs?
In what way does the oxygen of the air get to the tissue cells?
How does the CO_2 produced in the body get out?
What is the relation of respiration to circulation?
What is the relation of respiration to digestion?
Describe vital capacity.
How does expired air differ from inspired air?

CHAPTER XI.

THE DIGESTIVE SYSTEM.

THE COMPOSITION OF THE BODY.

VARIOUS parts of the body have been considered as to their form and structure. It has been shown that all the diverse forms of which the body is composed may be placed into five classes of tissue cells. These tissue cells may again be examined to see of what elements they are composed. It is found that the same elements, in varying amount and arrangement, are present in each. Consideration has been given to the combination of organs that form the mechanism by which may be carried to them, for their up-building, repair and, functioning, the substances of which the cells are made. Another mechanism provides for the gaseous requirements of the cells.

In the above mechanisms the blood is the purveyor of the substances needed by the cells: air, water, and food. Before they can serve the cells, these must be taken into the blood. Air and water are ready for immediate use, but food must undergo many changes before it can become a part of the blood. Food is needed for growth and repair, to maintain the heat of the body, and to provide its energy. As it may give pleasure, it induces a happy frame of mind which encourages good digestion.

Of all the materials needed, the most vital is air. Without it, we would die in a few minutes. There is more air available than anything else.

The next in urgency is water, as without this death ensues in a few days.

The least urgent of the three is food, as proved by the fact that persons have survived after abstaining from food for more than six weeks.

The indication for the need of water is thirst, which is usually referred to the mouth and throat, but water in the mouth does not always relieve thirst; water introduced into the circulation, does. The sensation of hunger for food is referred to the stomach, but if the stomach is removed hunger may be felt. The sensation is relieved by feeding per rectum. It is thus seen that hunger and thirst are the calls of the *tissue cells* for food and drink. The amount of food, drink, and air needed varies greatly according to the surrounding temperature, activity, and age of the individual. The energy used in the body is dependent upon food which before energy can be liberated must be made an integral part of the organism.

THE PROCESSES IN CONVERTING FOOD INTO THE HUMAN ORGANISM.

It is interesting to observe the history of the food that is going to be made into a human being, and to study the relationship between the methods of procuring food in these modern times, and the necessity for taking formal gymnastics or learning to play games.

Except in the tropics, where food grew with little effort on the part of man, food meant to the primitive races either the chase, the laborious tilling of the soil or the care of flocks and herds. Meat to eat had to be cut from an animal; perhaps the animal had to be caught and killed; the wood for the fire to cook it had to be gathered; the water in which it was cooked had to be carried from the spring. No matches being available, fire was made by laborious processes. Perhaps stones had to be heated and rolled into the pot to heat the water enough to cook the meat.

The head of the family that attended to getting such a meal did not need to go to "gym" classes to keep *fit*.

Now, the specialization of work of modern days is seen. We decide to have chops for dinner, and a telephone order to the butcher shop brings the article to the kitchen door. A match to the gas-stove broiler, with attention to the matter for rather less than ten minutes makes the chops ready to eat. Have we the appetite that the primitive family had for their meat? Does it taste as good—does it digest as well as for that other family? But, then how many people helped us get our chops? How many were concerned in the telephone; in the stock farm that raised the lamb; in the stockyards, where it was prepared for market; in the making of the retail butchers' shop; in the motor cars that delivered it; in the making gas for fuel, and the stove for burning the gas; the salt and pepper that seasoned the chops, and the dishes from which it was eaten?

If the above processes are elaborate they are not more so than the various stages through which food passes before it becomes a part of our structure.

These processes may be grouped as:

1. Prehension, or taking the food in the hands to put it in the mouth.
2. Mastication, or chewing by which it is divided and subdivided into small particles.
3. Deglutition, or swallowing which passes it along from the grinding room to the next station.
4. Gastric digestion, or the mechanical and chemical changes that it undergoes in the stomach.

5. Intestinal digestion, or the mechanical and chemical changes it undergoes in the intestine.

6. Absorption, or its taking up by the lymphatic and venous vessels.

7. Cell assimilation, or the building-up into the cell structure. This is the final step by which food truly becomes a part of one's self.

Foods which cannot yield energy are not affected chemically, but are dissolved, if not already in solution, and discharged from the body in the same state as when received. Foods which yield energy must be separated from the innutritious parts, and go through various changes.

ANATOMY OF THE ORGANS CONCERNED IN DIGESTION.

The process of digestion is begun in the mouth, and finished in the small intestine. To all intents and purposes, the alimentary canal may be considered as a tube passing through the body from the mouth to the anus. The food in it should be considered as outside the body until, by absorbent vessels, it is taken up from the tube. The alimentary canal begins with the mouth; it continues through the esophagus, stomach, small intestine, and large intestine. Accessory organs to the canal are the teeth, tongue, salivary glands, gastric glands, intestinal glands, liver, and pancreas.

These will be considered in order, before taking up the kinds of food presented to them for preparation.

The Mouth.—This is an irregularly oval aperture, formed by the superior maxillary bone, the mandible, and the cheeks, limited and closed by the lips in front. Its floor is formed by the tongue. It communicates posteriorly with the pharynx, superiorly with the nasopharynx, and inferiorly with the esophagus and larynx.

The mouth contains the teeth and the tongue. Opening into it are the ducts from three pairs of salivary glands. It is lined with mucous membrane, which, with the salivary secretion, keeps the mouth moist, so aiding in the appreciation of taste. Articulate speech is assisted by the mouth and its accessories. This cavity serves as a chamber in which mastication and insalivation of food can take place. By the contraction of the muscles in their walls, the cheeks help to move the food around, while the lips keep it from falling out of the mouth.

The hard palate forms the roof of the mouth with the soft palate attached to its posterior border. Dangling from the center of the soft palate is a process called the *uvula*. (Fig. 276.) This is concerned in articulation.

The imperfect development of the palate bones, resulting in what is known as "cleft palate" or "hare-lip" is a serious impediment to speech.

The Teeth.—These are hard white structures set in the margins of the superior maxilla and the mandible. They are for biting, tearing and grinding the food, the different groups having these special uses.

The teeth grow in two sets, one in infancy, the other in childhood and youth. The first set is superseded by the second, and so is called the *temporary* or *milk* teeth. The second set is called the *permanent* teeth.

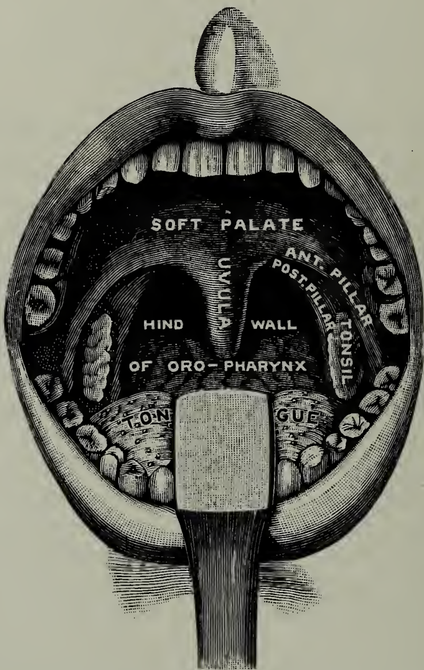

Fig. 276.—The soft palate and tonsillar regions. (Testut.)

In the first set are 5 teeth in each half of each jaw, or 20 in all. Beginning at the middle line, there are 2 incisors, 1 canine and 2 molar teeth. The first ones erupt about the seventh month. Dentition is usually completed by the twenty-fourth month. The teeth in the lower jaw normally precede those of the same group in the upper jaw. The order of eruption is: (1) The central incisors; (2) the lateral incisors; (3) the first molars; (4) the canines; (5) the second molars.

About the sixth year a molar tooth develops, which is the first of the permanent set. It is called the "six-year molar." About the seventh year the temporary set begins to be shed and is replaced by the permanent teeth. The 2 molars of the milk set are replaced by

2 bicuspids of the permanent set. The third molar is not developed until late adolescence and is popularly called the "wisdom tooth." (Fig. 277.)

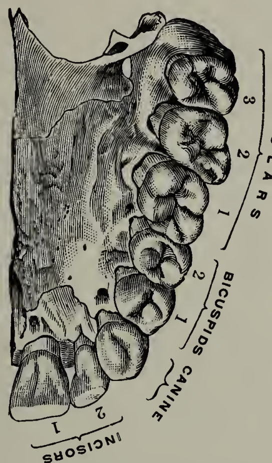

Fig. 277.—The teeth of the right half of the upper jaw in their sockets, viewed from below. (Gerrish.)

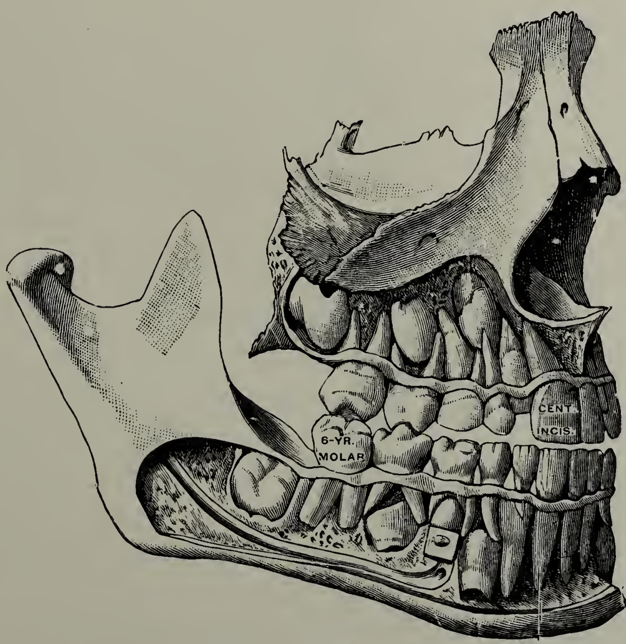

Fig. 278.—The jaws of a child of seven and a half years, the external table of bone having been cut away to show the stage of second dentition. (Testut.)

The temporary teeth are replaced by the permanent set at about the following years.

First molar, sixth year.
Two middle incisors, seventh year.
Two lateral incisors, eighth year.
First bicuspids, ninth year.
Second bicuspid, tenth year.
Canines, eleventh to twelfth year.
Second molar, twelfth to thirteenth year.
Third molar, seventeenth to twenty-first year.

The replacement of one set by the other occurs by the later-coming teeth in their growth absorbing the roots of the milk teeth, until only the crown remains. Little force is then needed to remove that. (Fig. 278.)

Parts of a Tooth.—A tooth is composed of three parts, crown, root and neck. The crown is the part that projects from the gums; the root is imbedded in the alveolar process of the jaws; and the neck is the slightly constricted part that is just under the gums. (Fig. 279.)

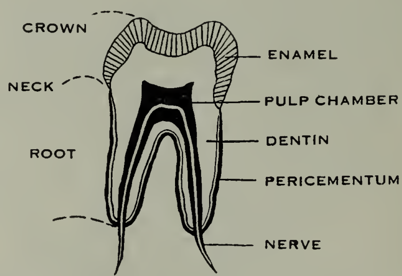

Fig. 279.—Diagram of the structure of a tooth.

The crown is composed of *dentin,* covered with enamel. Enamel is a form of epithelial tissue with the cells calcified. It is the hardest material in the body. The root tapers and fits into the bony sockets very neatly, thus avoiding uneven pressure.

In the tooth is a central cavity or pulp chamber. The pulp consists of a nerve (branch of the trifacial or fifth), bloodvessels, and cells in an areolar mesh.

The sockets of the teeth are lined with a form of periosteum, called the pericementum, which is reflected on to the root of the tooth as far as the neck.

The Uses of the Teeth.—Teeth aid in phonation, add to the attractiveness of the features, as well as helping to preserve the contour of the face. The front teeth are for cutting food, while the back teeth serve as grinders. The canines are for tearing the food. The surfaces of the upper molars fit in with those of the lower jaw,

each tooth being in contact with two opposite ones. The lower jaw moves on the upper in a side to side, antero-posterior and an up-and-down movement. Various muscles attached to the jaws, the hyoid bone, the sphenoid, and the temporal bone, are concerned in these movements. The force exerted through the molar teeth in grinding the food is estimated to be about 150 pounds.

The Tongue.—The tongue is a muscle, very mobile, changing in length and width at every contraction. It is an organ of the special sense of taste; an organ of speech, and it assists in mastication, insalivation, and deglutition. It is about 3½ inches long, covered with mucous membrane, under which is a layer of fibrous tissue. The upper surface is rough by reason of many papillæ. Their size varies, the smaller ones being in front, and a few (8 to 12) large ones, or *circumvallate papillæ,* toward the back. Most of the taste-buds are found in these circumvallate papillæ. (Fig. 236.)

The nerve supply, other than the gustatory nerve, is from the fifth and twelfth cranial nerves.

The tongue is very sensitive, as, on its surface there are the endings of many nerves of ordinary sensation. It gives information to the brain as to the size of the mass in the mouth and the stage of mastication reached.

Salivary Glands.—There are three salivary glands on each side.

The *parotid,* largest in size, is beneath and in front of the lobe of the ear. Stenson's duct carries the secretion. The *submaxillary* is below the mandible, near the angle of the jaw. The *sublingual* is under the mucous membrane of the mouth lateral to the middle line in front. The average amount of saliva secreted in twenty-four hours by the three glands is much over a liter. This is of alkaline reaction.

These glands all have ducts which open near the teeth, their secretion, *saliva,* being mixed with that from numerous mucous glands of the mouth. Their flow is increased by mastication and by the smell of appetizing food. (Fig. 280.)

The Tonsils.—Though the tonsils have no special relation to the digestive process, they will be considered here as connected with the mouth.

The tonsils are two ovoid bodies of varying size at the entrance to the pharynx between the anterior and posterior pillars of the fauces. (Fig. 276.) They are a collection of lymph nodules, covered by a capsule of fibrous tissue which sends trabeculæ into its substance, dividing the tonsils into many compartments. The surface next the fauces has 12 to 15 depressions or crypts which extend into the tonsil. Mucous glands open into these crypts. With their secretion is mingled great numbers of lymph cells.

The function of the tonsils is not understood. Apparently, they absorb and destroy pathogenic bacteria, if they are in a healthy

condition, but if enlarged and hardened they themselves seem to be a source of infection. In the fevers of children they become congested and enlarged. It is possible their protective function may end at the age of puberty, at which period a child becomes less liable to the infectious fevers. It is suggested they may also have an endocrine function.

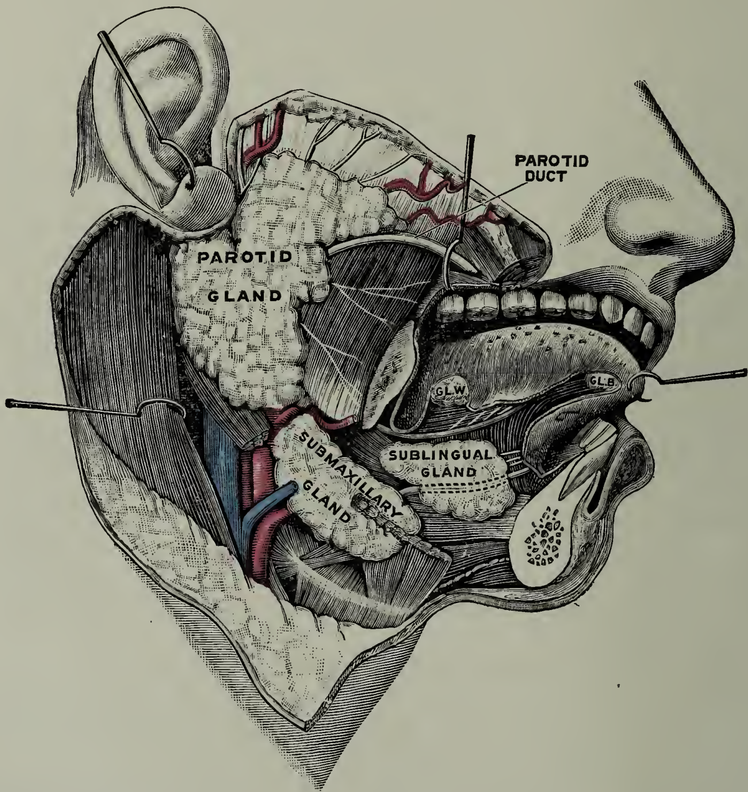

Fig. 280.—The salivary glands. The right half of the body of the mandible has been removed. GL. W., gland of Weber; GL. B., gland of Blandin. (Testut.)

The Esophagus.—The esophagus is a tube, 9 inches long, $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in diameter, which beginning at the pharynx, passes through the superior and posterior mediastinum, then through the diaphragm to the cardiac orifice of the stomach. It lies behind the trachea.

The coats of the esophagus or gullet are muscular and epithelial. The upper part of the muscular coat is of striated muscle, therefore under the control of the will. Further down there is a mixture of striated and plain muscle while at the lower part, only plain muscle tissue is found.

Liquids pass down the esophagus with no apparent effort, as though dropped. Solid or semi-solid food requires a peristaltic movement in the lower part of the tube. A peristaltic movement implies inhibition of circular fibers in front of a bolus of food, so it may pass forward by the contraction of fibers behind it. The movements of the middle and lower parts are involuntary and vermicular, moving the bolus of food toward the stomach. From this point, the work of digestion is carried on below the diaphragm or in the abdominal cavity. Only a few of the organs in the abdomen are not concerned in digestion.

The Abdominal Cavity.—The abdomen is the cavity in the lower part of the trunk, between the diaphragm above, and the brim of the pelvis below.

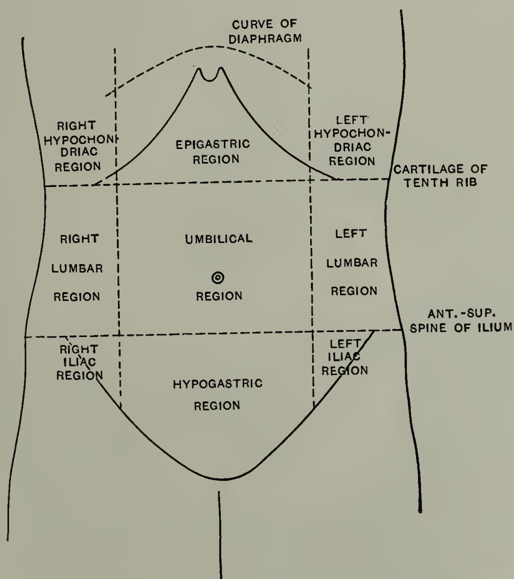

Fig. 281.—Regions of the abdomen according to the method of Gerrish.

It is bounded in front and on the sides by a muscular wall, which includes the rectus abdominis, obliquus externus abdominis, obliquus internus abdominis, and the transversus abdominis muscles. On the posterior lateral walls are the quadratus lumborum, psoas magnus muscles, and the iliac fossa, while the vertebral column is posterior. The dome of the diaphragm extends as high as the fourth rib, varying according to the respiratory movements.

The shape of the abdomen varies according to age and sex. In infancy, it resembles an inverted, truncated cone. The adult female is the reverse, with the male type more barrel-shaped but flattened antero-posteriorly.

The cavity is lined with serous membrane, called the *peritoneum.* This is reflected on the viscera. It enables the different organs to slip and slide for a short distance without friction. The organs contained in the abdominal cavity are: the stomach, liver, spleen, pancreas, 2 kidneys, 2 suprarenal bodies, the small intestine, the large intestine (except the rectum), the abdominal aorta, and its branches, the inferior vena cava, the beginning of the thoracic duct,

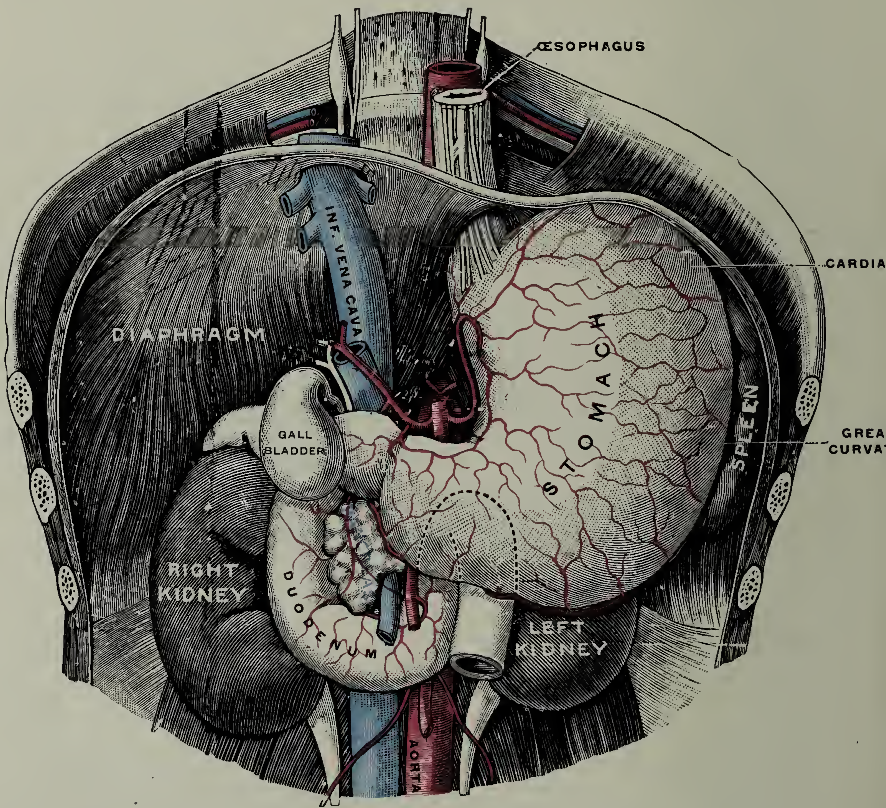

Fig. 282.—Stomach and duodenum, the liver and most of the intestines having been removed. The pyloric end of the stomach should be represented as turned directly backward. (Testut.)

the vagi, sympathetic ganglia, and nerves, besides numerous lymph nodes. For convenience in describing the structures contained in the cavity, the abdomen is divided into nine regions, though anatomists are not agreed as to the boundaries of them.

Following the arrangement described in Gerrish's *Anatomy,* two transverse planes cut the abdomen. One of these is at the level of the tenth costal cartilage, the other at the level of the anterior-

superior iliac spines. This forms three zones, the subcostal above, the umbilical in the middle and the hypogastric below. These zones are divided by two sagittal planes passing through the middle of Poupart's ligament.

Thus the abdomen has the umbilical region around the umbilicus, the right and left lumbar on either side of it. The epigastric region is above the umbilical, with the right and left hypochondriac on either side. The hypogastric is below the umbilical, with the right and left iliac or inguinal on either side. Apparently this leaves nothing in the hypochondriacal regions, but it should be remembered that the diaphragm domes upward, so that there is a greater space than appears on the surface. (Fig. 281.)

The Stomach.—The stomach is a pear-shaped viscus, located in the epigastric and left hypochondrium. (Fig. 282.) When active during the process of digestion, the shape is markedly changed, being elongated and narrowed in several sections. Just below the diaphragm, to the left of the middle line of the body, is the *cardiac orifice,* through which food enters the stomach from the esophagus. Lower down, to the right of the middle line, is the *pyloric orifice,* through which the food leaves the stomach.

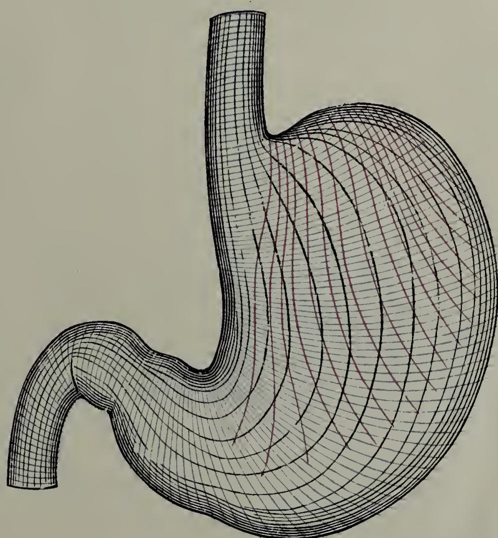

Fig. 283.—Diagram to show the direction of the fibers in the three muscular layers. (Testut.)

The expanded end of the stomach is the *fundus.* Except during the passage of food from the esophagus, the cardiac orifice is kept closed by the "sphincter cardiæ." During gastric digestion the pyloric orifice is closed except when it opens to allow digested food to pass out.

Between these two orifices, superiorly, the line of curvature of the stomach is called the "lesser curvature." The long way around, between the two is the "greater curvature." (Fig. 282.)

According to its contents, the stomach varies in size. When empty, the anterior and posterior walls are in contact with each other. When it is distended, its greatest length is about 14 inches, its transverse diameter 5 inches, and its capacity about 5 pints.

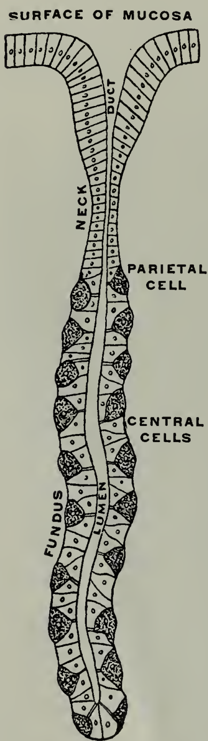

Fig. 284.—Cardiac gland in longitudinal section. (Gerrish.)

The stomach is nearly vertical when empty. When distended the pylorus is moved 2 inches toward the right, with the greater curvature tilted toward the front. It exerts considerable pressure upward on the diaphragm, with more or less consequent interference with the action of the heart.

The Coats of the Stomach.—Four coats invest the stomach, the serous or peritoneum, the muscular, the submucous and the mucous.

The *peritoneal coat* covers the stomach, front and back, passing from the lesser to the greater curvatures. The two layers fall free from the lower border, forming a fold like an apron, which covers the intestines. Doubling back, it wraps the transverse colon. This is the *great omentum.* It contains more or less fat and serves to protect the intestines from cold.

Muscular Coats.—The muscular coat varies in thickness from $\frac{1}{50}$ of an inch over the cardiac end to $\frac{1}{12}$ of an inch at the pylorus. It consists of three layers of unstriated muscle. The outer layer is longitudinal, the middle layer circular, and the inner layer oblique in direction. (Fig. 283.)

The muscular fibers increase in thickness at the pyloric end, forming a thick ring-like sphincter, called the *pylorus.* A similar thickening at the cardiac orifice is called the "sphincter cardiæ." In the muscular wall are two groups of autonomic nerves, the plexi of Auerbach and of Meissner. Similar groups are found in the muscles of the intestines.

The Submucous Coat.—This is a layer of loose-meshed areolar tissue, in which the larger bloodvessels and nerves are imbedded. The elastic nature of this tissue protects the bloodvessels and nerves from pressure, while allowing free movement between the muscular and mucous coats.

Mucous Coat.—This is $\frac{1}{25}$ of an inch thick, consisting of columnar epithelium, resting on a basement membrane. The mucous membrane is divided into numerous polygonal depressions from the

bottom of which extend gastric glands. (The honey-comb tripe of the markets illustrates these depressions in a larger way.)

Gastric Glands.—The gastric glands are tubular. They secrete the gastric juice which contains *pepsin, rennin, lipase,* and *HCl.* The glands nearest the pyloric end secrete mostly pepsin, while those at the fundus (large end), secrete both acid and pepsin. (Fig. 284.)

Gastric Juice.—The gastric juice is a thin, almost colorless fluid of acid reaction, and a specific gravity of 1003 to 1005. Free hydrochloric acid is produced to the amount of about 0.2 per cent to 0.3 per cent, to acidify the secretions and stomach contents. The smell of appetizing food will initiate the formation of this juice, which is increased in amount by the presence of food in the mouth As the masticated and insalivated mass enters the stomach and is subjected to the action of the muscles, the maximum amount of secretion occurs. In twenty-four hours from 3 to 7 pints are made.

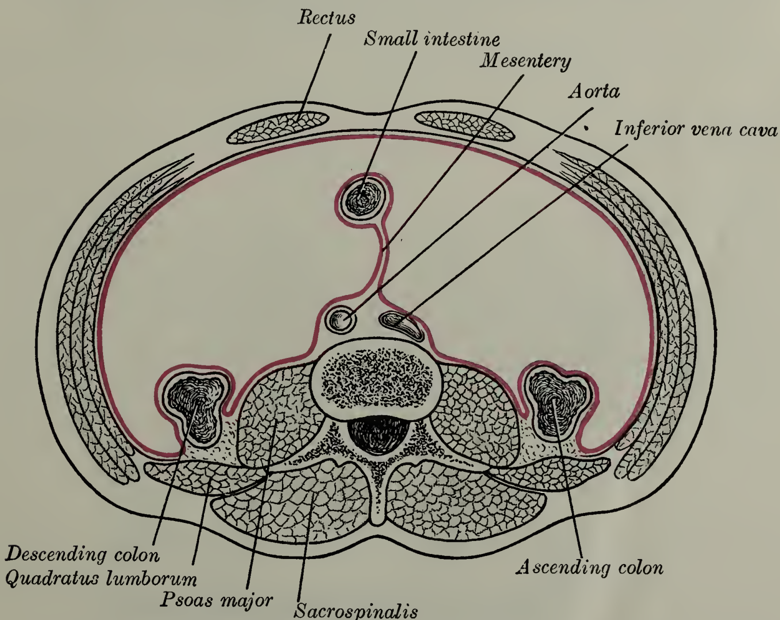

FIG. 285.—Horizontal disposition of the peritoneum in the lower part of the abdomen. (Gray.)

The Small Intestine.—Leaving the stomach through the pyloric orifice, the contents pass into the first part of the small intestine. For about 10 inches this is the *duodenum.* The rest of the small intestine makes up a total length of some 20 feet. This is divided into two parts, the *jejunum* and the *ileum.*

No distinct boundary separates these parts, but the first 8 feet is usually accepted as the jejunum.

The small intestine is a tube, averaging about $1\frac{1}{4}$ inches in diameter and laid in the middle of the abdomen in a series of apparently

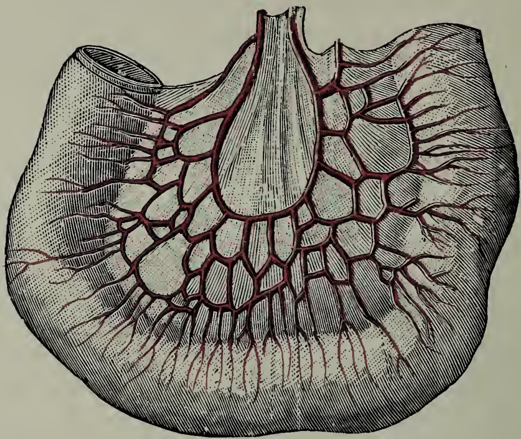

FIG. 286.—A loop of small intestine, showing the mode of distribution of the arteries. (Testut.)

tangled loops. At its distal end it opens into the cæcum, the beginning of the large intestine. (Fig. 286.)

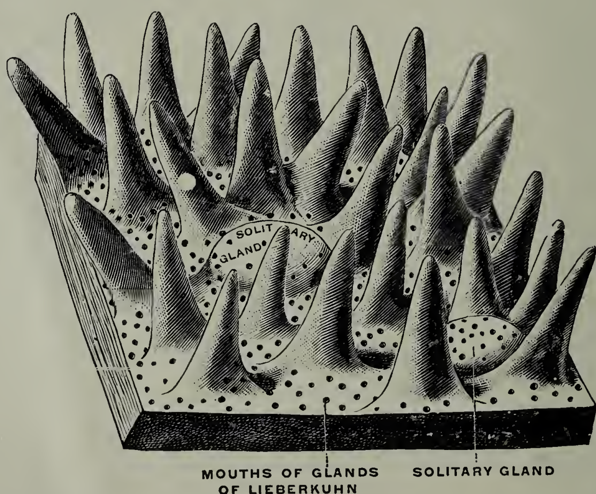

FIG. 287.—Free surface of the mucous membrane of the small intestine, showing villi, solitary glands and openings of the intestinal glands. Semidiagrammatic. (Testut.)

Coats of the Small Intestine.—There are four layers in the walls of the small intestine, a serous, a muscular, a submucous and a mucous coat in the order named from without inward.

The *serous* coat is the peritoneum. This starts from the anterior surface of the vertebral bodies as a sheet of tissue. It envelopes the tube and then goes back to the vertebral bodies. This anchors the coils firmly and forms a smooth, slippery covering for the intestine, so it may move freely, but be held in place. This structure is called the *mesentery*. Between its two layers are the intestinal branches of the abdominal aorta; the corresponding veins; the nerve plexi, and lymphatic vessels with their glands or nodes. (Fig. 285.)

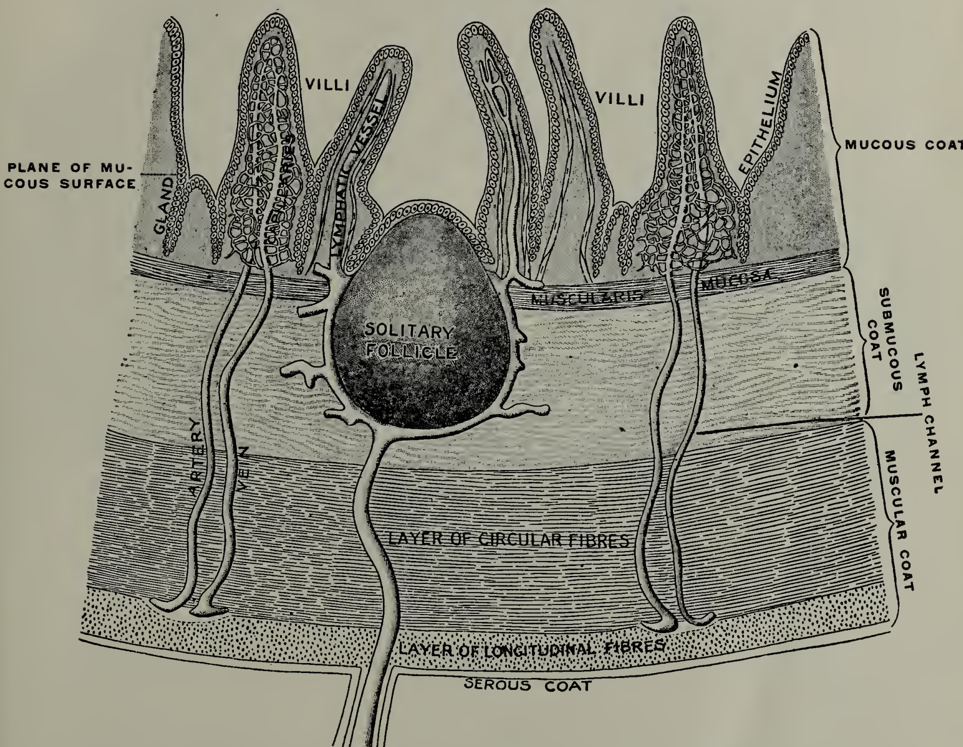

FIG. 288.—Mucosa of small intestine in ideal vertical cross-section. (Testut, after Heitzmann.)

The *muscular* coat is in two layers, one longitudinal and the other circular.

The *submucous* coat is of areolar tissue with a network of blood-vessels, nerves and lymphatics imbedded in it.

The *mucous* coat on the inner surface presents a velvety appearance and many ridges. The ridges are the *valvulæ conniventes*, which increase the working surface of the tube, holding the food in contact with the digestive juices for a longer period.

Villi.—The velvety appearance is due to some 4,000,000 to

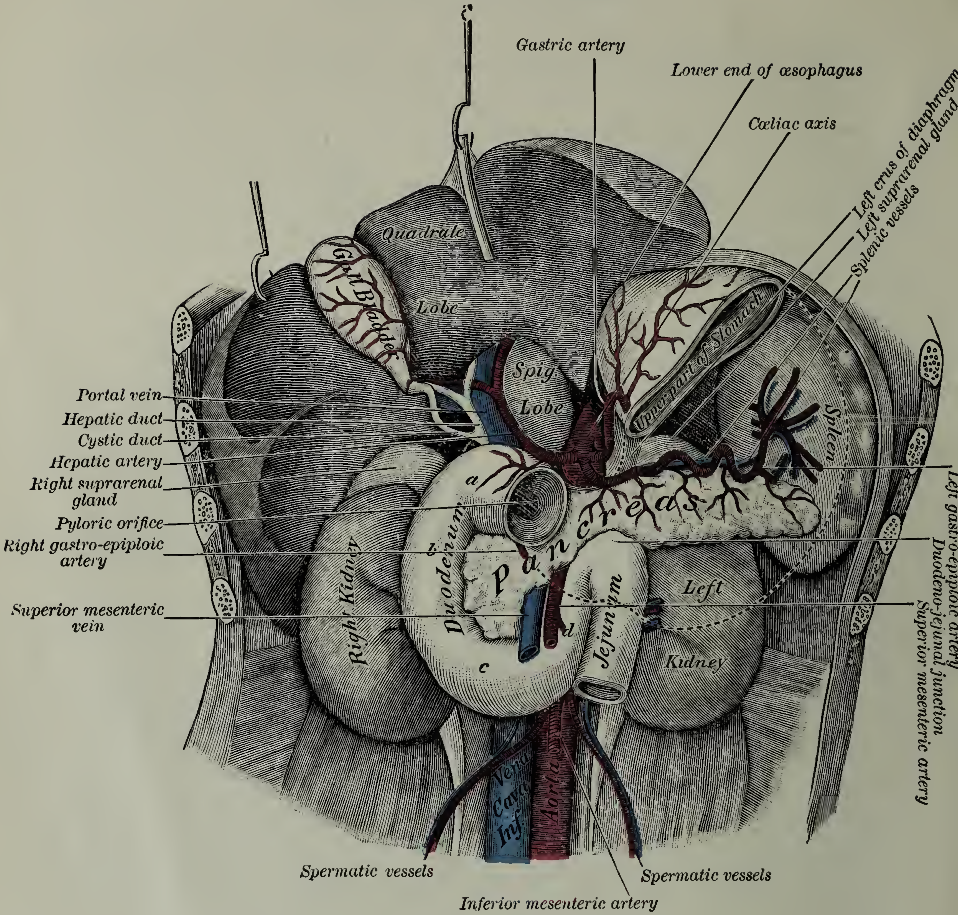

FIG. 289.—The duodenum, its four parts marked *a*, *b*, *c*, *d*. The liver is lifted up; the greater part of the stomach is removed, broken lines indicating its former position. (Testut.)

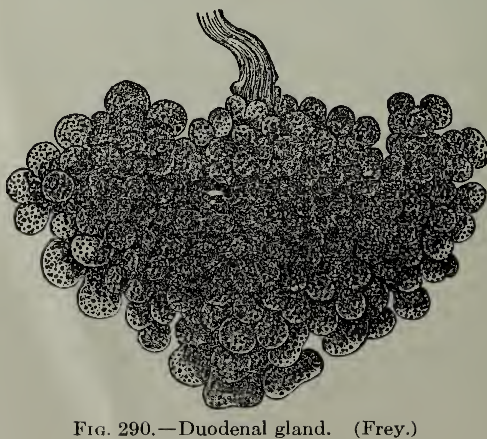

FIG. 290.—Duodenal gland. (Frey.)

10,000,000 villi. These are organs of absorption. They are less than $\frac{1}{25}$ of an inch in height and $\frac{1}{70}$ of an inch in diameter. (Fig. 287.)

The villi are conical or cylindrical in shape with a lymph radicle in the middle. (These are special lymph vessels called lacteals). Around the lacteal is a network of capillaries, some unstriated muscle fibers and a mass of nucleated cells. The whole is covered by columnar epithelium. (Fig. 288.)

Crypts of Lieberkühn.—In the mucous membrane are many tubular glands (crypts of Lieberkühn) which secrete the *succus entericus* or intestinal juice, and mucus.

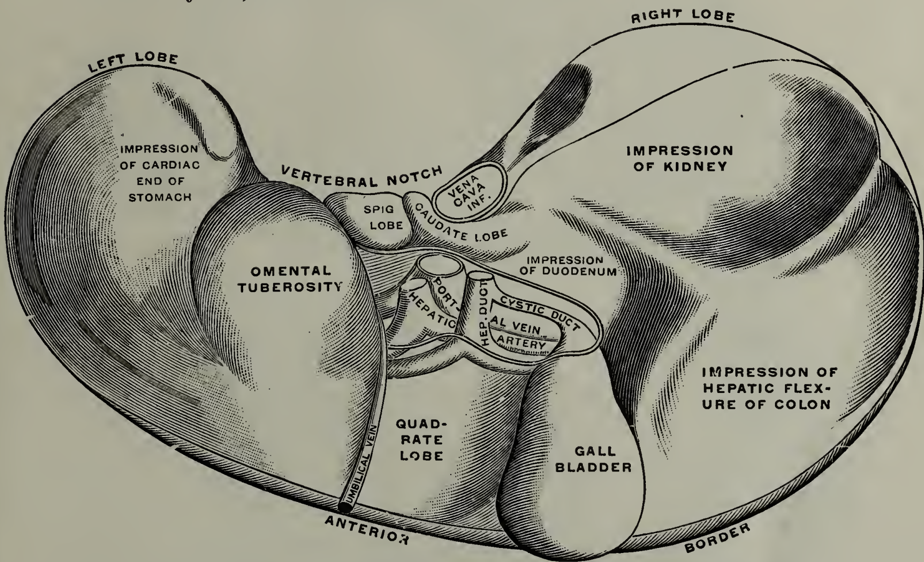

FIG. 291.—The liver, lower surface. (Drawn from the His cast.) (Gerrish.)

Lymph Nodules.—In the walls of the intestine are small bodies that are similar to lymph nodes. These are *solitary glands,* and their work is related to that of the nodes in the mesentery. (Fig. 288.)

The Duodenum.—The duodenum is the first 10 inches of the small intestine. It winds around the head of the pancreas (Fig. 289), and receives a secretion from that organ, from its own peculiar glands (Brunner's glands), and bile from the liver. (Fig. 290.)

There are two organs in the abdomen that are accessory to the alimentary tract: the *liver* and the *pancreas.*

The Liver.—The liver is in the upper right quadrant of the abdomen, extending beyond the middle line to the left. It is the largest gland in the body, weighing between 3 and $3\frac{1}{2}$ pounds. It is wedge-shaped, with the greatest width 8 to 9 inches, with a height of 6 to 7 inches, and its antero-posterior diameter 4 to 5 inches. The

base of the wedge is to the right. It is of soft solid consistency, friable, and a dark reddish-brown in color.

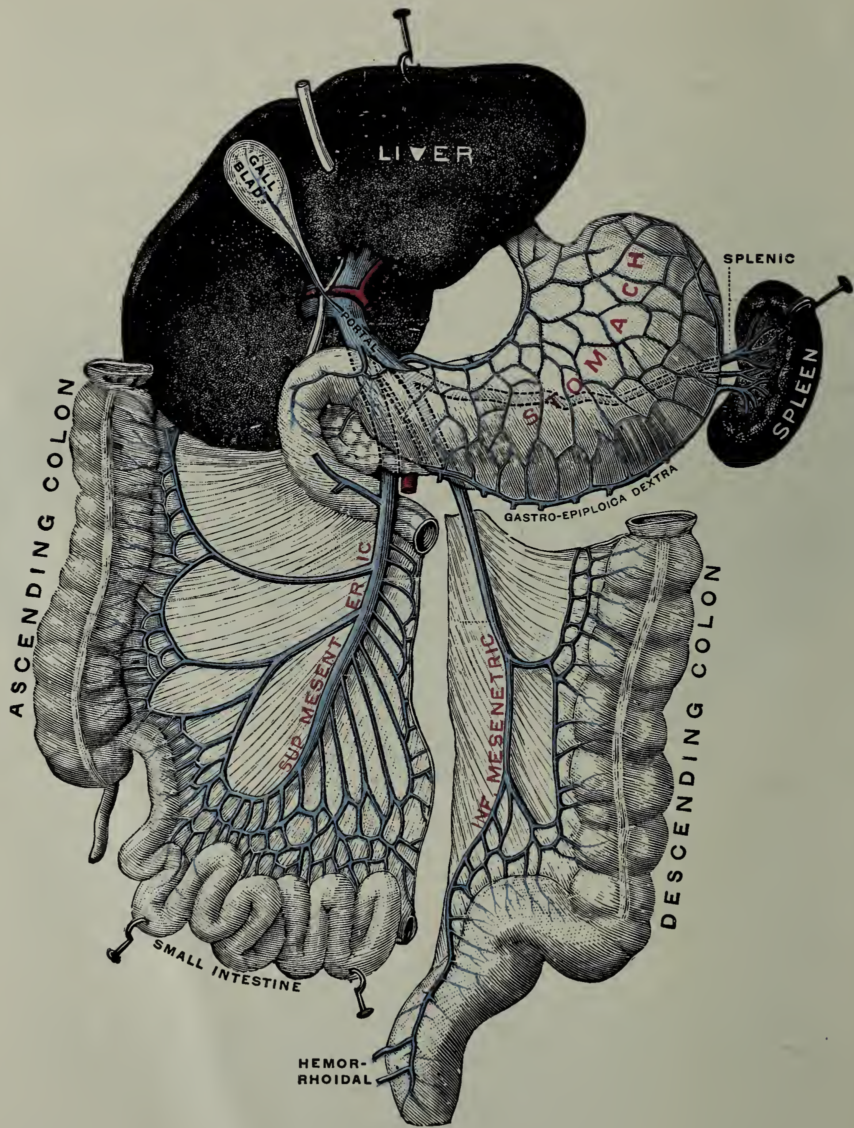

Fig. 292.—Portal system of veins. The liver is turned upward and backward, and the transverse colon and most of the small intestines are removed. (Testut.)

The liver is divided by five fissures into five lobes. The left and right lobes are primary divisions; the right lobe is subdivided into

the quadratus, spigelii, and caudatus. The fissures give passage to bloodvessels. The gall-bladder lies in one of these fissures. (Fig. 291.)

The liver is attached to the under surface of the diaphragm, and to the anterior wall of the abdomen by folds of peritoneum. It is covered with a fibrous membrane, which forms a capsule. The substance of the liver is made up of small units of structure called *lobules.* These are held together by areolar tissue and by the ramifications of the portal vein, hepatic artery, hepatic vein, bile ducts, lymphatics and nerves.

The Lobule.—This is the working part of the liver, the laboratory in which the numerous functions of the liver take place. They are small granular bodies about $\frac{1}{20}$ to $\frac{1}{10}$ of an inch in diameter, with irregular outlines. The lobules have in the center a small vein which issues from it, carrying the collected blood from the portal vein capillaries and those of the hepatic artery. Around this vein the hepatic cells are grouped in radiating columns, as closely packed as possible, leaving room only for the capillaries of the portal veins, the bile ducts and nerves on the sides. The cells are abundantly supplied by the portal vein with material which includes newly digested food. From this, bile is manufactured and given off to the small ducts on the sides of the cells.

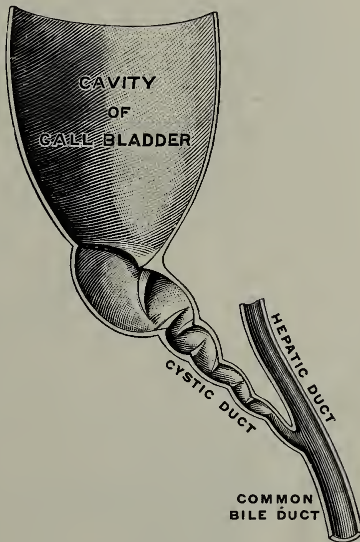

Fig. 293.—The cystic duct in section, with part of the gall-bladder, hepatic and common bile ducts. (Testut.)

Blood also comes to the lobule by way of the capillaries of the hepatic artery. This supply is mainly concerned with the nutrition of the lobule itself. The venous capillaries which arise after the lobule is supplied, carry off by way of the hepatic vein to the vena cava, the blood which has come in through the portal vein.

Gall-bladder.—The gall-bladder is about 4 inches long, pear-shaped, and holds about 1 ounce. It is on the under surface of the front edge of the liver. (Fig. 293.) In the process of digestion, bile is used, being poured out in the duodenum on the entrance of the food of an acid reaction from the stomach. The bile so used has been stored in the gall-bladder, following its previous formation. The small ducts of the right lobe unite into a large duct; those of the left lobe do the same, and the two ducts form one large vessel,

the *hepatic duct.* The cystic duct expands its free end as the gall-bladder. Here the bile is stored until needed, when it passes down out of the bladder through the *cystic duct.* The cystic duct unites with the hepatic duct to form the "ductus communis choledochus," or common bile duct. This opens into the duodenum about 4 inches beyond the pyloric end of the stomach.

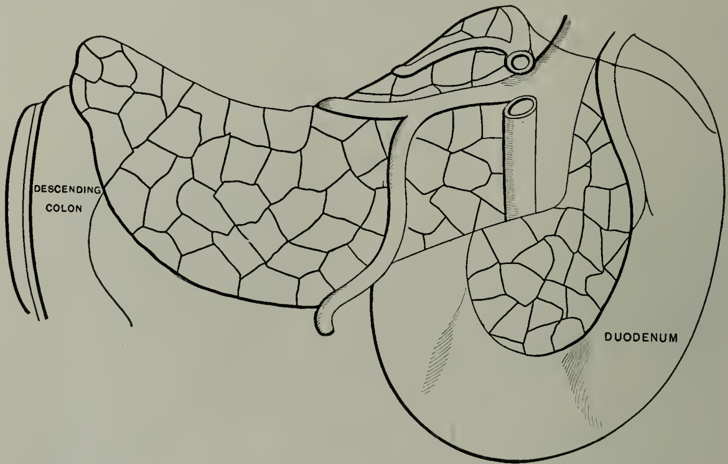

FIG. 294.—The pancreas, dorsal view. The head is seen in the embrace of the duodenum. The portal vein and superior mesenteric artery lie behind the neck. (Drawn from the His cast.) (Gerrish.)

The Pancreas.—This is a large gland in the upper part of the abdomen, behind the stomach. It is somewhat hammer-shaped, with the head embraced by the duodenum. It is about 6 inches long, 1½ inches wide and from ½ to 1 inch thick. (Fig. 294.)

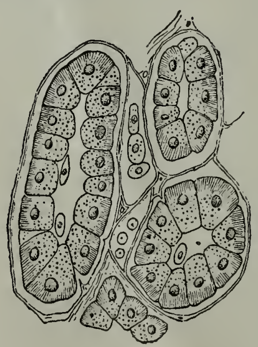

FIG. 295.—Cross-section of pancreatic acini. (Testut.)

It is pinkish in color and weighs between 2 and 3 ounces. The structure of the pancreas is that of a compound tubular gland The tubes are coiled in small masses called lobules, with the cells short and conical. (Fig. 295.)

In its work the gland is similar to the salivary glands, secreting pancreatic juice which passes out through the duct of Santorini into the duodenum (Fig. 296).

This gland has other cells than those concerned in the production of pancreatic juice. The so-called "islands of Langerhans" have to do with forming an internal secretion which profoundly influences nutrition. Its internal secretion "insulin," affects the digestion of sugars.

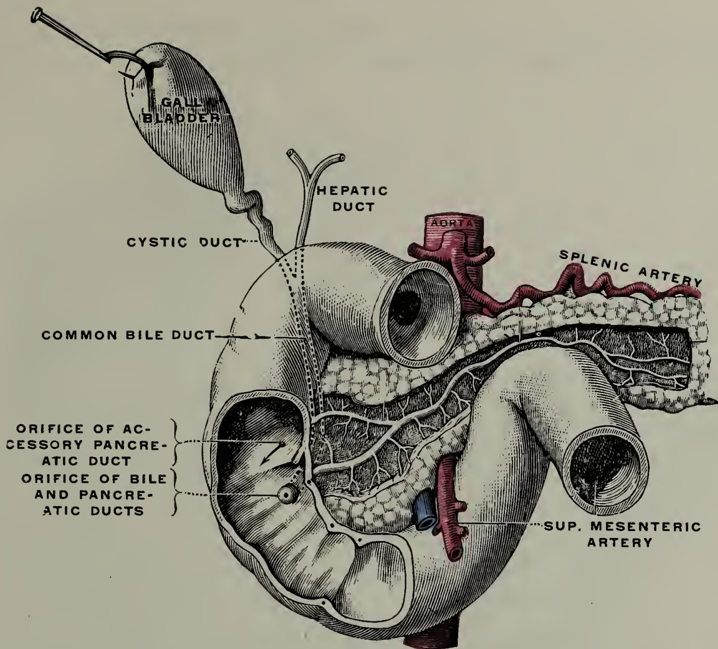

FIG. 296.—Ducts of the pancreas. Part of the front wall of the duodenum is cut away. (Testut.)

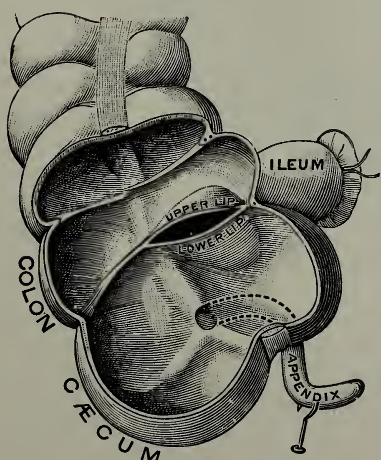

FIG. 297.—Cavity of the cæcum, its front wall having been cut away. The ileocæcal valve and the opening of the appendix are shown. (Testut.)

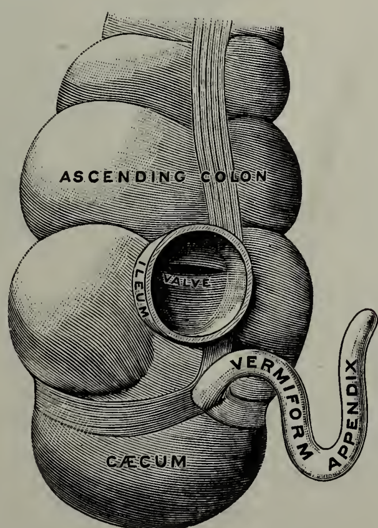

FIG. 298.—The cæcum, dorso-mesial view, showing the ileum-side of the ileocæcal valve, and the beginning of the three muscular ribbons. (Testut.)

Removal of the pancreas with resulting loss of its internal secretion causes death in two or three weeks.

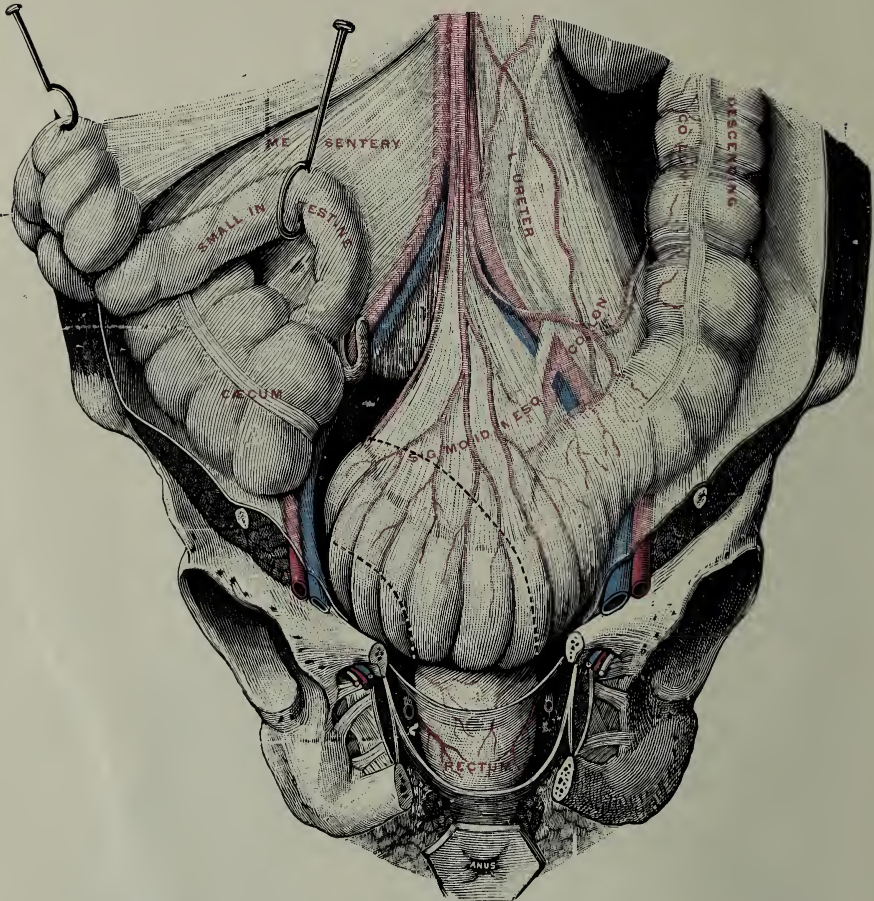

Fig. 299.—Sigmoid colon and rectum, front view. The broken lines indicate the situation of the concealed part of the sigmoid colon. The small intestine is drawn away, and the anus is turned forward. (Testut.)

The Large Intestine.—The large intestine is about 5 feet long and 4 inches in diameter. It is divided into the *cecum,* the *colon* (ascending, transverse, descending, and sigmoid flexure), and the *rectum.* The cecum is a blind pouch at the beginning of the colon, in the lower right side of the abdomen. At the termination of the ileum the small intestine opens into the large intestine at the *ileo-cecal* valve. This is a fold of mucous membrane shaped like a nipple at the opening into the cecum, which prevents regurgitation. This is important as the contents of the large intestine may contain putrefactive bacteria. The valve prevents also, a too rapid passage of

material from the small intestine, *i. e.*, before complete digestion and absorption. From the cecum a small tube, called the *vermiform appendix*, passes downward and backward. (Figs. 297 and 298.)

Leading from the cecum is the colon in four parts. The ascending colon passes up on the right side of the abdomen as high as the liver. There it turns (hepatic flexure), and crosses the abdomen as the transverse colon at the level of the anterior-superior spine of the ilium.

On the left side it turns (splenic flexure); and as the *descending colon*, passes downward to about the level of the pelvic brim. Here it makes an "S"-shaped turn, becoming the *sigmoid flexure*. In the back of the pelvis this becomes the *rectum*, which terminates at the surface middle line as an opening, the *anus*.

The large intestine has three coats. The outer, peritoneal, is the extension of the peritoneum.

The middle coat consists of two layers of plain muscle fibers, an inner circular layer, and the outer longitudinal layer. The latter fibers are placed in three bands. Being shorter than the tube, the surface is puckered, forming saccules which delay the progress of the contents for a longer period.

The inner coat is mucous, containing neither villi nor valvulæ conniventes. It does have many mucous follicles, the cells of which secrete a large amount of mucus.

THE PHYSIOLOGY OF DIGESTION.

In the adaptation of man to his environment, if energy is expended there must be a replacement of the materials from which energy is derived. Otherwise, man does not survive. Knowing what elements are present in the body, we have a guide to what must be replaced, provided, we ascertain from the examination of the wastes just what has been used. This examination considers the total output of the body in energy and waste products, including urea, water, CO_2, and other materials. This output is compared with the total taken in, including O, water, and food.

The Composition of Foods.—Of foods there are many, but on analysis they are found to consist in varying proportions of

Water.
Mineral matter.
Protein.
Carbohydrate.
Fat.
Vitamins.

The body is made up of these same elements (see the Composition of the Plasma in Chapter II) in many different combinations, both solid and liquid, organic and inorganic.

Water.—This forms about 70 per cent of the body weight. It acts as a solvent in the body, rendering materials capable of absorp-

tion. It is a constituent of every tissue. In varying proportions, it is in every kind of food. In addition to the amount taken in an ordinary diet, about 3 pints daily are considered necessary. This may be increased or decreased according to the activity, temperature, and food taken.

The Inorganic Compounds.—These are formed from some fifteen chemical elements. Upon their correct proportion and balance depend the health and efficiency of the organism.

These elements, with their percentages as occurring, are as follows:

	Per cent.
Calcium	1.300
Carbon	13.500
Chlorine	0.085
Hydrogen	9.100
Nitrogen	2.500
Oxygen	72.000
Phosphorus	1.150
Potassium	0.026
Sodium	0.100
Sulphur	0.147
Fluorine, Iodine, Iron, Magnesium, Silica, Manganese	Small and varying quantities.

Of these elements, calcium forms three compounds—the carbonate, the fluoride and the phosphate. In the blood the carbonate is combined with CO_2. All three give to the bones and the teeth their solidity and hardness.

Sodium provides four compounds—the carbonate, the chloride, the phosphate, and the sulphate.

Sodium chloride is very abundant, being in every tissue of the body, but especially in the blood. It is instrumental in the diffusion of liquids. Water gets into the blood mainly on account of the contained sodium chloride. The carbonate and phosphate, also in every tissue, imparts alkalinity to them.

Potassium forms three compounds—the carbonate, the chloride, and the phosphate. These are usually associated with the sodium compounds and have similar effects.

Magnesium has the carbonate and the phosphate—the former in the blood, while the latter forms a part of all the tissues.

Iron is a constituent of hemoglobin.

Iodine is combined with materials in the thyroid gland, as its internal secretion. It is also in the liver, bile, small intestine, blood and lungs.

Numerous other compounds are formed during the life processes, as acetic, hippuric, lactic, oxalic and uric acids; alcohol, glycerin, cholesterin, urea, creatin, bilirubin, indol, etc.

Various forms of malnutrition follow the absence of these salts from the dietary. They should always be in the food, though modern methods of refining frequently result in robbing it of these necessary elements.

The Organic Compounds.—These are *protein, carbohydrate* and *fat.*

Chemically, *protein* consists of carbon, hydrogen, oxygen, nitrogen and sulphur, in varying proportions, with more or less phosphorus and other inorganic salts. Many forms of protein exist, some of which are not represented in the human body. Some are relatively simple in structure; others very complex.

In general, proteins cannot pass through an animal membrane; they can be coagulated. Under the influence of bacteria, in a warm, moist atmosphere, with oxygen, they will decompose and putrify. These processes result in the formation of simpler compounds, as hydrogen sulphide, carbon dioxide, ammonia, nitrates, and phosphates. In the presence of acids, alkalies, and enzymes (ferments), proteins break up into amino-acids and diamino-acids, which appear to be their ultimate divisions. These nitrogen-holding bodies, of which some twenty different combinations have been isolated, include alanin, arginin, cystin, glycocoll, histidin, leucin, lysin, tryptophan, tyrosin, etc.

Proteins constitute 20 per cent of muscle and 30 per cent of osseous tissue. They are essential in the repair of broken-down cell structure. Therefore, it is the one food that is absolutely necessary to continued existence. It can take the place of fats and carbohydrates as energy producers. The latter cannot be substituted for protein as a rebuilding material.

According to their structure, a division of proteins is made into "simple," "conjugate or combined" proteins, and protein derivatives.

The *simple proteins* include:

1. *The Albumins.*—These are soluble in water, in a normal saline solution and in a saturated solution of sodium chloride and magnesium sulphate. They can be coagulated by heat

   Serum albumen, is found in the blood, lymph, and chyle. The protein of wheat is in this group.

   Egg albumen, resembles serum albumin, but is not found in the human body.

   Lac albumen, is the albumin of milk.

   Myo-albumen, is in the muscle plasma.

2. *The Globulins.*

   Serum globulin, a constituent of serum.

   Fibrinogen, the antecedent of fibrin, in the blood plasma.

   Myosin and *myogen,* in the muscle plasma.

   Globulin, or crystallin, in the crystalline lens of the eye.

3. *The Albuminoids.*—They form important elements in the framework of the body. They are most difficult to dissolve. These include:
   Collagen, in fibrous connective tissue, and the ground substance in bone. It may be converted into gelatin.
   Ossein, in osseous tissue.
   Chondrigen, in cartilage.
   Elastin, in elastic fibrous tissue.
   Keratin, in hair, nails, etc.
4. *Phospho-proteins.*—Containing phosphorus.
   Caseinogen, in milk.
   Vitellin, in egg-yolk. Vitellins are apt to have much lecithin.

Conjugate, or Combined Proteins.—In these compounds the protein is united with other substances as carbohydrates, nuclein, and coloring matter. They have an important part in building-up of cells. *Hemoglobin, mucin,* and *nucleoprotein* are in this group. Hemoglobin contains the protein *globin,* with hematin, an iron-containing body. Nucleoproteins form a large part of the nucleus of cells. Nucleins when decomposed yield the *purin* bases, as xanthin, adenin, guanin, etc., plus phosphoric acid.

The Protein Derivatives.—These represent the proteins as they step down in complexity during the process of digestion under the influence of enzymes. They include *acid-albumin, alkali-albumin, proteoses, peptones* and *polypeptids.*

The Carbohydrates.—These are mostly starches and sugars. They are composed of carbon, hydrogen and oxygen. The atoms of carbon are always six or some multiple of six. The hydrogen and oxygen are in the same proportion as they are in water.

The *starches* include those found in grains, vegetables and fruits *Amylose* is a general name for them.

Glycogen is a starch in the liver cells and muscles.

Dextrin is an intermediate product between starch and sugar.

Cellulose is the framework of vegetable cells. It is not digested in the human alimentary tract.

The *sugars* include:

Dextrose ($C_6H_{12}O_6$), glucose, or grape sugar, is absorbable sugar, as present in the blood, liver, and muscle tissue. It is the end-product when starch is digested.

Levulose or fructose is found in fruit sugar and in honey, mixed with glucose. Cane sugar may be converted into glucose during digestion.

Lactose or galactose is the sugar in milk.

Maltose is the sugar in malt, derived from starch.

Saccharose is cane or beet sugar.

Dextrose is the only form of sugar that can be used in the body. The others must be transformed or inverted into dextrose before they can be absorbed.

The Fats.—These are also compounds of carbon, hydrogen and oxygen, but the proportion of oxygen is very small as compared with those of carbon and hydrogen. *Stearin,* the hardest fat has composition, $C_3H_5(C_{18}O_{35}O_2)_3$. It does not melt at the body temperature.

In man fat is found in the subcutaneous tissues, around viscera, in the yellow marrow, and in milk.

The Need for Repair and Replacement of Materials.—The cells of some organs have relatively long resting periods between the working periods. Others have only momentary times for rest. But, whether they are actively at work or practically resting, the life processes involve a constant breaking-down of the tissue cell.

The fact that an animal given adequate water but no food progressively loses weight is sufficient evidence of a constant need for repairs and replacement of materials in the living body, varying according to the activity undergone.

Classes of Food and How Digested.—Having considered the apparatus by which food is digested it remains to describe the kinds of food according to their chemical composition.

Very few foods are purely and strictly in one class. Most of them being a combination, in varying proportions, of carbohydrates, protein, and fats.

A glance at the table following will show the percentages of the three classes in some of the commoner articles of diet. The meats have much water, considerable protein, some fat, but little carbohydrate. They are classed as protein food. Certain vegetables as beans and peas contain little water, as much protein as meat and considerable starch. They are the vegetable proteins.

Proteins are either animal or vegetable and are found in many forms. Among them are casein in milk and cheese; albumen in the white of egg; vitellin in the yolk of egg; myosin and syntonin in meat; gluten in flour; legumen in peas and beans, and the protein in nuts. Among the common foods that are predominantly protein are: lean meat, milk, eggs, cheese, fish, wheat, oatmeal, peas, beans, and peanuts. The animal proteins are more easily digested than those derived from vegetable sources, and contain less waste.

The digestion of proteins occurs in the stomach, and the small intestine, in the presence of the proteolytic enzymes, pepsin, rennin, trypsin, and erepsin.

As proteins are stable in their composition, they are used in the body for repairing and building-up the cells.

The various so-called carbohydrate foods contain small quantities of protein in many cases, but are mainly starches and sugars. The starches are found in cereals, potatoes, some fruits, and legumes. The sugars include cane sugar, maple, beet, grape, malt, and milk sugars, as well as that found in meat.

AVERAGE CHEMICAL COMPOSITION OF FOODS.[1]

Food materials.	Water, per cent.	Protein, per cent.	Fat, per cent.	Carbo-hydrates, per cent.	Ash, per cent.	Fuel value calories, per pound.
Beef:						
Sirloin steak	61.9	18.9	18.5	.....	1.0	1130
Round steak	67.8	20.9	18.6	.....	1.1	835
Veal, leg	71.7	20.7	6.7	.....	1.1	670
Lamb, leg	58.6	18.6	22.6	.....	1.9	1300
Chops broiled	47.6	21.7	29.9	.....	1.3	1665
Mutton:						
Roast leg	50.9	25.9	22.6	.....	1.2	1420
Pork, loin	66.5	18.9	13.0	.....	1.0	900
Smoked ham	39.8	16.5	38.8	.....	4.7	1945
Chicken	70.3	21.9	7.4	.....	1.1	835
Fish:						
Cod	82.6	16.5	0.4	1.2	...	325
Salmon	64.6	22.0	12.8	1.4	...	950
Eggs	73.7	13.4	10.5	.....	1.0	720
Butter	11.0	1.0	85.0	.....	3.0	3605
Buttermilk	91.0	3.0	0.5	4.8	0.7	165
Cheese:						
American	31.6	28.8	35.9	.....	3.5	2055
Full cream	34.2	25.9	33.7	2.4	3.8	1959
Cream	74.0	2.5	18.5	4.5	0.5	910
Whole milk	87.0	3.3	4.0	5.0	0.7	325
Skimmed milk	90.5	3.4	0.3	5.1	0.7	170
Cracked wheat	10.1	11.1	1.7	75.5	1.6	1685
Macaroni	10.3	13.4	0.9	74.1	1.3	1665
Oatmeal	7.3	16.1	7.2	67.5	1.9	1860
Rice	12.3	8.0	0.3	79.0	0.4	1630
Flour:						
Fine white	13.8	7.9	1.4	76.0	0.5	1625
Entire wheat	11.4	13.8	1.9	71.9	1.0	1675
Bread:						
White	35.3	9.2	1.3	53.1	1.1	1215
Entire wheat	38.4	9.7	0.9	40.7	1.3	1140
Sugar, fine white	....	....	....	100.0	...	1860
Vegetables:						
Green butter beans	58.9	9.4	0.6	29.1	2.0	740
Fresh carrots	88.2	1.1	0.4	9.3	1.0	210
Green corn	75.4	0.8	1.1	19.7	0.7	470
Green peas	74.6	7.0	0.5	16.9	1.0	465
Boiled potatoes	75.5	2.5	0.1	18.4	1.0	385
Fruits:						
Apples	84.6	0.4	0.5	14.2	0.3	290
Bananas	75.3	1.3	0.6	22.0	0.8	460
Grapes	58.0	1.0	1.2	14.4	0.4	335
Nuts:						
Almonds	4.8	21.0	54.9	17.3	2.0	3030
Chestnuts	45.0	6.2	5.4	42.1	1.3	1125
Peanuts	9.2	25.8	38.6	24.4	2.0	2560
Walnuts	2.5	18.4	64.4	13.0	1.7	3300
Chocolate	5.9	12.9	48.7	30.3	2.2	2860
Cocoa	4.6	21.6	18.9	37.7	7.2	2320

[1] Abstracted from "Food Values," by Edwin A. Locke.

Carbohydrates are the least expensive of the various kinds of food and constitute the larger bulk of the articles eaten. They are easily oxidized and converted into heat and muscle energy, and into fatty tissue, when taken in excess of the body needs. The digestion of starches occurs in the mouth and small intestine in the presence of the amylolytic enzymes, ptyalin, amylase and pancreatic diastase.

Carbohydrates enter the blood as dextrose. Its oxidation results in the production of heat, kinetic energy, H_2O and CO_2.

The digestion of sugars occurs in the small intestine, in the presence of the sugar-splitting enzymes.

Fats are either animal or vegetable. The principal forms, according to their firmness are stearin, palmatin, margarin and olein. They are found in most of the animal foods, in the dairy products and in nuts. Various vegetable oils are derived from the seeds of cotton, from corn, etc. Fats form a powerful fuel food, giving heat and energy, but are rather difficult to digest and oxidize. The outside envelope of fats is removed in the stomach by the gastric juice, but their digestion takes place in the small intestine by means of bile and steapsin.

The Chemical Changes in Digestion.—These are effected by the presence of certain substances called "enzymes." Various observers have given different definitions to this term. Oppenheimer suggests the following:

"An enzyme is a substance produced by living cells which acts by catalysis. The enzyme itself remains unchanged in this process, and each enzyme exerts its activity only upon substances whose molecules have a certain definite arrangement."

Small quantities can initiate changes in much greater amounts of material. They are not stable in their composition.

Enzymes act to the best advantage at the body temperature, but are destroyed in a high temperature. They never completely convert the substance upon which they act. If these substances are removed as fast as formed, the enzyme keeps on acting.

Enzymes are divided into many classes according to the substances acted upon by them. The majority of those known are active in the digestive tract. There are others, of which little is known, whose spheres of activity are within the various cells of the body. The principal of these, according to the food affected, are:

1. The proteolytic, or protein-splitting enzymes. They cause a hydrolytic splitting of the protein molecule.

2. The amylolytic, or starch-splitting enzymes. They cause a hydrolytic splitting of the starch molecule.

3. The lipolytic, or fat-splitting enzyme.

4. The sugar-splitting enzymes. Two groups of these, one of which converts the double sugars into the single sugars or monosaccharids; the other splits the monosaccharids.

5. The coagulating enzymes which convert soluble into insoluble proteins.

Of the above group the proteolytic enzymes include:

Pepsin, in the gastric juice, which converts proteins into peptones and proteoses.

Trypsin, in the pancreatic juice, which splits proteins into their constituent amino-acids.

Erepsin, in the small intestine, which splits peptones and proteoses into their constituent amino-acids.

The amylolytic enzymes include:

Ptyalin, in the saliva, which converts starch to sugar (maltose).

Amylase, in the pancreatic juice, saliva, liver, and blood serum, which converts starch to sugar (maltose and dextrin).

Liver glycogenase, in the liver, which converts glycogen to dextrose.

Muscle glycogenase, in the muscles, which converts glycogen to dextrose.

Invertase, in the small intestine, which converts cane sugar to dextrose and levulose.

Maltase, in the small intestine, saliva, and pancreatic juice, which converts maltose to dextrose, or glucose.

Lactase, in the small intestine, which converts lactose to dextrose and galactose.

Lactic acid enzyme, which changes glucose to lactic acid during muscular work.

The fat-splitting enzymes include:

Lipase or *Steapsin,* in the pancreatic juice, liver, blood, etc., which splits neutral fats into fatty acids and glycerin.

The hydrolytic action of an enzyme consists of a molecule of the affected substance, in the presence of an enzyme, taking up water, the new molecule subsequently splitting into two or three simpler ones.

Salivary Digestion.—In the mouth, mastication initiates the process of digestion. This grinding or mastication is aided by the tongue, lips, and cheeks, which hold the food in contact with the teeth, and these with the saliva to moisten the food, initiate the process of digestion.

A harmonized action of sensory and motor nerves informs the brain of the condition of the food in the mouth, and transmits the orders for the continuation or suspension of mastication and insalivation. The sensory nerves concerned in this coördination are fibers of the trigeminal and the glosso-pharyngeal.

The motor nerves are motor fibers of the trigeminal, the hypoglossal, and the facial. The nerve centers are in the medulla.

The action of the muscles of mastication is voluntary, though it continues after the attention has been diverted. Apparently, by

reflex action, the messages as to the state of the food, result in continued activity, either in chewing or swallowing.

The more thoroughly mastication is performed, the better can the digestive fluids get at the food. The saliva moistens it, but, also, acts chemically upon the starches by the presence of *ptyalin.*

Starch, especially cooked starch, plus water, in the presence of *ptyalin,* takes up a molecule of water. It then breaks down into a soluble starch which, later, splits into maltose and dextrin. The further conversion of maltose into dextrose takes place in the small intestine.

Saliva also aids in the appreciation of taste by keeping the mouth and tongue moist. By the same means, it aids phonation. Its secretion is stimulated by the thought of appetizing food. In some emotional states, as fear, it is diminished.

Saliva has an alkaline reaction. A slight amount of acid added, enough to neutralize the fluid, makes it more effective in the digestion of starches.

Deglutition.—After the food has been thoroughly masticated and insalivated, deglutition follows with almost no effort. If the preceding processes have not been well performed, there must be a definite muscular effort to swallow the bolus of food. This is done by the aid of the constrictor muscles of the pharynx. (Fig. 300.)

Deglutition requires an elaborate series of coördinated movements in which the food is carried from the back of the tongue, through the pharynx, into and through the esophagus, and then into the stomach. It is also prevented from going backward into the nose or into the larynx. The action is partly voluntary, partly reflex, the different coördinations occurring through centers in the medulla.

Gastric Digestion.—The food which enters the stomach is usually composed of various elements, as protein, carbohydrates, fats, and cellulose.

By the action of the teeth and saliva in the mouth the food has been, more or less, finely divided and softened. It is alkaline in reaction, and the starches have been more or less digested. The HCl in the stomach changes this reaction to acid.

Movements of the Stomach.—Apparently, during gastric digestion the stomach divides into two parts. Between the cardiac orifice and that of the pylorus there is set up a series of circular muscular contractions that move toward the pylorus in peristaltic waves. This produces a tube-like area, the fundus remaining more quiescent. Consequently, the food in the fundus is not immediately acidulated and the digestion of the starches may continue for some time.

Meanwhile a portion of the food is subjected to a series of squeezing movements, plus the chemical action of the gastric juice. These combined, change the food to a semifluid consistency, or to the so-called chyme. As this change occurs, the peristaltic waves of

circular contractions involve the pylorus, causing it to open. Some of the stomach contents goes into the duodenum, after which the pylorus closes again. These waves come every fifteen or twenty seconds.

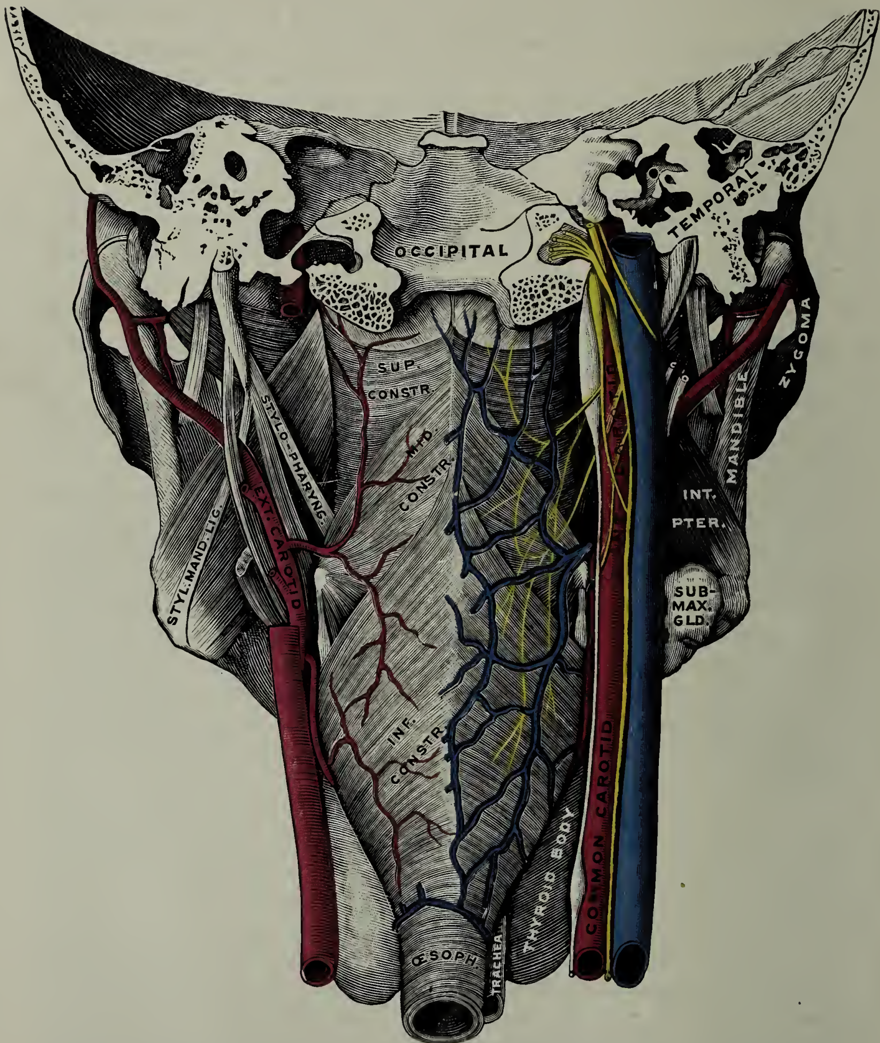

Fig. 300.—Muscles of the pharynx, viewed from behind, together with the associated vessels and nerves. (Modified from Testut.)

Compression of the fundus by the oblique and longitudinal muscle fibers carries another portion of food to be similarly treated. This goes on until the stomach is emptied, which may require from two to five hours, according to the class to which the food belongs.

The carbohydrates pass out of the stomach early in the process of gastric digestion. Proteins usually require some two hours before passing out of the stomach. Fats, other than that of milk, delay the secretion of gastric juice. They remain a long time in the stomach and pass out very slowly.

In the early part of digestion the gastric juice contains an excess of acid. This, causing the pylorus to open, is ejected into the duodenum, where it stimulates the formation of the alkaline bile and pancreatic juice. Reversal of the peristaltic wave carries this alkaline material back into the stomach, where it partly neutralizes the extreme acidity of the contents. By this means, the food sent later into the duodenum is not so irritating to its lining.

Of the enzymes in the gastric juice, *pepsin* converts some of the proteins into soluble peptones, that is, into material that will pass through the walls of capillaries and tissue cells. They can, therefore be absorbed from the digestive tract and into the cells.

Pepsin requires an acid medium in which to act. This condition being fulfilled by gastric juice, the protein is first made acid, or is changed into acid protein or syntonin, by hydrolysis.

Hydrolysis may be considered as the process, by which, in the presence of a ferment or enzyme, a substance takes up an atom of water, and then splits up into simpler compounds. Successive steps in the splitting may result in smaller molecules as well as simpler combinations, making the ensuing substance more easily soluble.

From syntonin, the supposed steps are to primary proteoses, to secondary proteoses, to peptones and possibly to amino-acids.

The protein and the resulting peptone are made up of amino-acids in varying number and arrangement, according to the kind of protein. Amino-acids are the units or building stones, out of which the protein molecule is constructed.

The second enzyme, *rennin*, coagulates the casein in milk, so it becomes insoluble. After this, the pepsin acts upon it to digest it. It is claimed by some that rennin is the same as pepsin. That the casein of milk is coagulated by pepsin if lime salts, as calcium chloride, are present.

The third enzyme, similar to one found in the pancreatic juice, is *lipase*, which digests the fat of milk.

These enzymes in the stomach do not, as a rule, completely digest the proteins, except the albuminoids, such as gelatin.

The envelope of fat cells is broken by the action of pepsin, and the oil therein contained is set free.

Vegetables having a cellulose framework are disintegrated in the stomach, though their protein is less easily acted upon than that of animals.

After these processes are completed, the material leaving the

stomach is called *chyme.* This is of the consistency of pea soup, with minute particles of solid food suspended in a liquid.

The Nerve Supply to the Stomach.—The nerves by which these processes are controlled are partly autonomic, partly cerebrospinal.

The vagus causes tonicity of the muscles, in the absence of which no peristalsis occurs. It is also concerned in secretion. The vasomotor impulses to the bloodvessels, determining the amount of blood supplied, come from the medulla oblongata *via* cells in the lateral horn of the spinal cord in the thoracic region, and from the semilunar ganglion.

The secretory nerves of the epithelial cells originate in cells near the floor of the fourth ventricle. The sensory impressions that initiate and continue this activity, come from the mucous membrane of the mouth, tongue and stomach, and from the cerebral regions associated with the sight, odor, and taste of food.

This nerve supply indicates the reflex stimulation of the gastric glands. The conditioned reflexes, which provoke a flow of gastric juice at the sight, smell, or thought of food, together with afferent impulses from the mucous membrane of the mouth, start a preliminary secretion. The more extensive flow, after food enters the stomach, is attributed to the action of a hormone produced in the cells of the mucous membrane of the pylorus. This hormone in the blood stimulates secretion from the gastric glands.

A strongly alkaline material, baking soda, taken on an empty stomach, passes into the duodenum and inhibits gastric secretion. Taken with or after food, it increases secretion by its action on the mucous membrane of the pylorus.

The plexi of Auerbach and Meissner supply nerves to the muscular coats of the stomach and, possibly, coördinate their activity.

The Blood Supply to the Stomach.—The blood supply to the stomach is through the gastric artery with anastomosing branches from the hepatic and splenic (lienal).

Intestinal Digestion.—In the small intestine much more of the digestive process occurs than in the stomach. The *chyme* enters the small intestine, in that very important section, the *duodenum.*

As this material is received, the formation of the alkaline pancreatic and intestinal juices, and the bile is stimulated. A hormone secreted by the intestinal glandular cells and then going to the pancreas is called *secretin.* This activates other glands to secrete alkaline materials (bicarbonate of soda, etc.), to neutralize the acidity of the material received from the stomach, in addition to stimulating the secretion of the pancreatic juice. Secretin influences the flow of intestinal juices. These, mixed with the chyme, neutralize it, more or less completely, so providing a medium in which the intestinal enzymes can act. Gastric digestion stops. The intestinal or final digestive steps are inaugurated.

The 10 inches of small intestine called the duodenum is responsible for a large part of the work of digestion. Into it opens the duct carrying bile from the liver and that carrying pancreatic juice.

Suppose an ordinary dinner to be eaten. This would represent a combination of water, meat, bread, butter, vegetables (either the green leafy kind, the starchy or those containing protein) mineral salts and some sweet or fruit. All the classes of food will be represented.

The carbohydrates by mastication, should have had some digestion in the mouth, so that after passing through the stomach, they will be represented by maltose and dextrin in the chyme.

The proteins, either partly or wholly digested in the stomach, in the chyme appear as acid protein, proteoses and peptones.

The fats, with their envelopes digested in the stomach, appear in the chyme as oil globules, more or less fine. The cane, malt and milk sugars have not been changed. The mineral salts, indigestible parts of the food, as cellulose, etc., and water are included in the acid mixture which passes from the stomach into the duodenum.

Pancreatic and Intestinal Enzymes.—The pancreatic secretion contains several enzymes: *amylose, erepsin, trypsin,* and *lipase.* The enzymes in the pancreatic and intestinal juices, while requiring an alkaline or neutral medium in which to act, may be said to combine those of the mouth and stomach.

Amylose or *amylopsin* is an agent that is more energetic than ptyalin in starch conversion.

Trypsin acts upon proteins, carrying their cleavage a step further than does pepsin, *i. e.,* the peptones are split up into the amino-acids or the final nitrogen-holding simplest compounds. Trypsin from the pancreas is inert until it is activated by the substance, *enterokinase.* This is a part of the "succus entericus" or intestinal juice. When thus activated, it becomes more powerful than pepsin in the conversion of proteids into their ultimate amino-acids. Amino-acids are formed and taken up shortly after the chyme reaches the duodenum. Still another enzyme in the pancreatic juice and in the intestinal juice which apparently acts in the same way is *erepsin.*

Steapsin or *lipase* changes the fats into acid bodies (stearic, palmitic, and oleic acids) and glycerin. As HCl is formed in the stomach, another chemical, the carbonate of potash or soda, an alkali, is formed in the intestine. This unites with the fatty acids and forms a soap. The rest of the oils divide into minute globules which are suspended in the liquid soap as an emulsion. This conversion of fat into an emulsion is facilitated by the *bile* which increases the activity of the lipase.

The Intestinal Juice.—The intestinal juice, derived from Brunner's glands and those of Lieberkühn, contains several enzymes, given

below. It has been suggested that the enzymes of the intestinal juice act on the foodstuffs in their passage through the epithelial cells of the small intestine, while they are on their way to the blood-vessels by which they are absorbed.

Erepsin is supposed to complete the conversion of protein into the amino-acids which can be absorbed directly into the blood stream and into the tissue cells, where they may be rebuilt into protein. This enzyme is said to be present in most of the body tissues. It has a rapid effect in completing the final cleavage of proteins.

Invertase or *saccharose* will change cane sugar to dextrose and levulose.

Maltase changes malt sugar or maltose to dextrose. The salivary digestion has converted starch into maltose, so here the change makes it capable of absorption.

Milk sugar or lactose is converted into dextrose and galactose by *lactase.*

These are the principal compound sugars that are ingested, which must be made absorbable and assimilable by the intestinal secretion.

The *bile* from the liver is of a dark greenish-red color, bitter in taste and odorless. It helps in the emulsification of fats, promotes intestinal peristalsis, inhibits putrefaction in the intestinal tract and promotes the absorption of fats.

Functions of the Liver.—There are other functions of the liver in addition to the secretion of bile. In the lobules of that organ the nitrogenous waste of the blood, which has come in through the portal vein, is worked over into a new substance called *urea.*

This is really an internal secretion of the cells, as it does not pass off through ducts as the bile does, but goes back into the blood. Still a third function of the liver cell is the storage of glycogen. Glycogen, a form of starch, is formed from the dextrose in the blood of the portal vein. It is stored in the liver cells, and when the muscle cells need fuel a portion of glycogen is reconverted to dextrose to pass to the muscle *via* the blood stream. The need for fuel is more or less constant, but the digestive process is intermittent. Hence, the necessity for a storehouse from which a supply may be doled out for the hourly need.

It is evident that dextrose, itself, being absorbable, could not be stored, so the two changes must be made, in which sugar is changed back to starch, stored and later, again converted into dextrose.

After changing dextrose to glycogen, the liver cells are the storehouses, with a supply ready to be taken up by the blood and carried to the parts where it is used. Glycogen could also be considered as an internal secretion, since it passes back into the blood instead of into a duct.

A fourth function is the conversion of the products of the putre-

faction of proteins in the intestine, as indol, skatol, phenol, etc., into compounds that are afterward excreted by the kidneys. The liver also produces fibrinogen, which is essential to the clotting of blood. Vitamins are stored in the liver. Some substance is produced which has to do with the regeneration of red cells.

Insulin Functions of the Pancreas.—The islets of Langerhans in the pancreas secrete a hormone which regulates the sugar metabolism. This will be considered more fully in the section on carbohydrate metabolism.

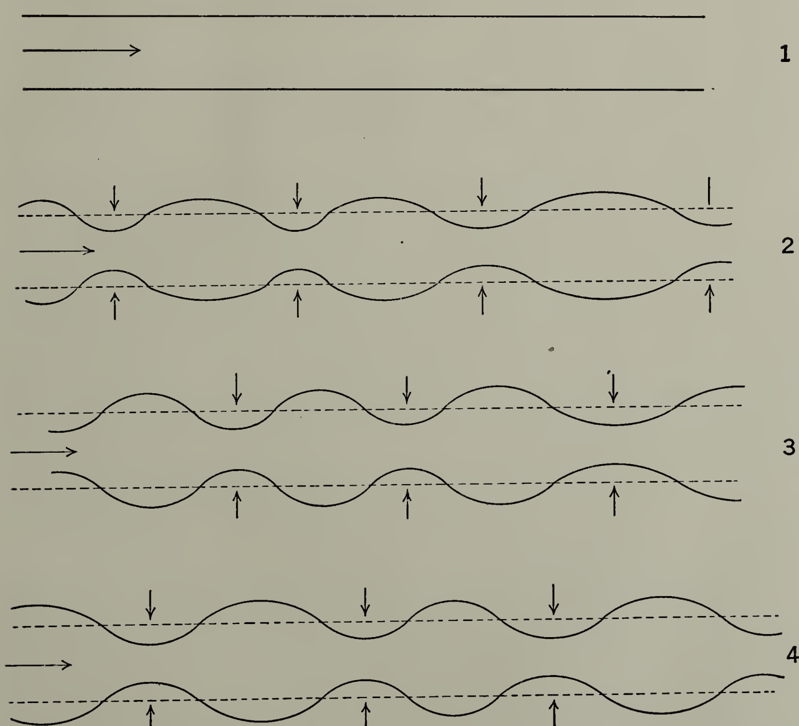

FIG. 301.—Rhythmic segmentation (adapted from Cannon). 1, a segment of the small intestine; 2, same segment with four constrictions, due to contraction of circular fibers; 3, four new areas of constriction at midway of former action; 4, same as 2.

Movements of the Intestine.—The movements of the intestine consists of a series of contractions by the circular muscle fibers. A section of the tube undergoes contraction by which the contained food is squeezed and brought into contact with the digestive juice. This contraction is in the form of a series of rings, which presently are changed in location, so the spaces that were previously between the rings become constricted. This continues for a time, and then by the peristaltic wave the food is moved along to another place

in the tube, where the process is repeated. This is called by Cannon *rhythmic segmentation.* (Fig. 301.)

As the digestion proceeds, and the food passes along the intestine, those elements that have been sufficiently acted upon are picked up by the epithelial cells that cover the villi.

The carbohydrates and protein pass from the cells into the capillaries of the intestinal loops, while the fats go from the cells into the lymphatics in the villi. These lymph vessels, called lacteals, unite and empty into the *receptaculum chyli,* from whence the *chyle* (as the digested fat is called) passes through the *thoracic duct* into the subclavian vein.

The digested carbohydrates and protein are taken by the capillaries into the venous radicles of the superior mesenteric vein, and thence into the portal vein, on the way to the liver. (See Portal Circulation, page 303.)

Absorption.—The combination of forces acting on the food in the intestine, chemical, thermal and mechanical, reduce it to a condition in which it will pass through the walls of the capillaries and the lymph radicles into the general circulation. Throughout the 20 feet of small intestine this absorption takes place until the material reaches the beginning of the large intestine. Little then remains except the waste of the food (that is, the parts of the food that cannot yield nourishment), undigestible material, and water. This arrives at the beginning of the large intestine, about twelve hours after it was first ingested.

The material brought to the large intestine is liquid, containing water, the undigested remnants of the food, mineral matters, parts of the bile. These mix with the mucus from the inner lining of the tube, forming the *feces.*

The Feces.—These are carried along by the peristaltic action as far as the middle of the transverse colon. Then a reverse peristaltic wave carries them back toward the cecum. This back-and-forth movement effects a more thorough mixture of the contents, and provides a longer time for the absorption of the water. By this absorption the feces become of a soft solid consistency, varying in color from light yellow to black, according to the character of the food and the length of time they remain in the tube.

As the feces are subjected to the peristaltic movements of the intestines, they pass on through the transverse and descending colon, finally being stored in the sigmoid flexure. Here they remain until their presence initiates a desire for *defecation,* or their expulsion, when they pass into the rectum and then out of the body. This is effected by the peristaltic action of the intestine, aided by the compression provided by the contraction of the diaphragm and the muscles of the abdominal wall.

The *rectum* is not a reservoir for the feces, but simply a passage

way. An internal sphincter, an inch above the anus, is surrounded by involuntary muscle fibers, and remains closed, preventing the escape of feces until they enter the rectum. At the anus an external ring of sphincter muscles is under the control of the will.

Intestinal Fermentation.—When food in excessive quantity has been taken or the digestive enzymes are defective, their stay in the intestine is prolonged, resulting through the action of the many bacteria which are found here, in fermentation or putrefaction.

The "intestinal flora," so-called, comprise bacteria that promote either fermentation or putrefaction. It is supposed that animal food elements undergo putrefactive changes, while vegetable products undergo those of fermentation. Hence, an excessive meat diet causes very offensive smelling feces. Among the numerous products of these changes are *indol,* an antecedent of indican, and *skatol,* which gives the odor to the feces. These are carried in the portal vein to the liver, and later are excreted by the kidneys.

Gases are also produced, such as sulphuretted hydrogen.

About twelve or thirteen hours are needed for the passage of the feces through the large intestine. In about twenty-four hours after food is eaten the waste is ready to be expelled from the body.

Blood Supply of the Intestines.—The small intestine receives its blood supply from the *superior mesenteric* artery, with anastomosing branches from most of the divisions of the abdominal aorta. In a like manner the main supply of the large intestine is from the *inferior mesenteric.* The branches usually run in the mesentery that supports the coils of intestines, and they then subdivide in the submucous coat.

Nerve Supply to the Intestines.—For the activity of these organs the vasomotor nerves regulate the amount of blood supplied. Secretory impulses come through the vagus from centers in the medulla to the cells. The activity seems to be initiated by sensory messages from the intestinal walls, which are produced by the presence of food.

There are sensory nerves associated with the organs in the thoracic and abdominal cavities. When the function of these organs is normally performed, no sensory impressions of which we are conscious arise from them. But, in abnormal or pathological conditions, decided sensations of pain compel attention. In this way Nature gives warning of the necessity for a rest of the part or of the need for attention.

However, these sensory impressions, while not affecting consciousness, initiate reflex activity.

Sensory fibers arise in cells of the ganglia of the dorsal nerve roots in the thoracic and lumbar nerves. These fibers go in the white rami communicantes to nerve centers, which transfer the stimuli to nerve trunks that go to the various organs. The cardiac

plexus carries these fibers to the heart; the splanchnic nerves to the abdominal viscera; the sacral nerves to the pelvic viscera.

When food materials, having undergone "rhythmic segmentation," send afferent messages as to its condition the initiation of the peristaltic wave follows, as a reflex action.

Afferent fibers, then, carry impulses to centers in the spinal cord and arborize around the cells of the center. From these cells efferent axons pass out to the sympathetic ganglion (semilunar) as preganglionic fibers and arborize around cells in the ganglion. From their ganglion cells other axons, gray postganglionic fibers pass to the plain muscle fibers in the intestinal walls. Or, they may in a similar way go to the glandular cells.

The "rhythmic segmentation," so-named by Cannon, appears to be initiated by the pressure of food on the intestinal walls, and to be carried on through their own power, by the muscle cells without the mediation of the plexi in the walls, or of the ganglia of the sympathetic.

The activity of the large intestine is due to impulses of similar kind from the lower lumbar and sacral nerves.

QUESTIONS.

What relation exists between the composition of the body and the composition of the common foods?

Name the processes in converting food into a part of the body in the order of occurrence.

What chemical agents are involved in digestion?

What mechanical agents are involved in digestion?

Name the enzymes acting on food in the stomach, in the mouth, in the intestine.

What are the uses of teeth?

Name and locate the salivary glands.

What are the functions of the tonsils?

What are the successive steps in the digestion of proteins?

What is glycogen? Where does it originate?

Describe "villi." Of what use are they?

What are "lacteals"?

Describe a lobule of the liver.

What secretion is produced in the "islands of Langerhans"? Its use?

What are the parts of the large intestine, and their uses?

What parts of the body depend upon the liver?

CHAPTER XII.

DIETETICS, NUTRITION, AND ANIMAL HEAT.

REQUISITES OF A DIET.

It is important to consider what quantity and in what proportion the various classes of food are essential to health. In the study of this problem, stated portions of the three principal food elements are burned to determine their value as fuel. The unit of measurement is the *Calorie,* that is, the amount of heat necessary to raise 1 kilogram of water 1° C. in temperature. This investigation fixes the fuel value of carbohydrates and proteins at 4.1 Calories per gram and that of fat at 9.3 Calories per gram. These values assume a diet in which 60 per cent is vegetable and 40 per cent animal food. In vegetable protein there is less heat value than in animal protein. A slightly lower caloric value is estimated for the usual mixture of food.

The analysis of the excreta, the products of perspiration, and respiration, shows the amount of carbon and nitrogen, plus the water that is excreted in a given time. This shows the amount of tissue that has broken down by oxidation. As the proportion of the elements in food products is known, it is evident how much food has been consumed, and how much must be taken to replace it.

Various investigators have examined these relations, and arrived at various results. The principal variant is as to the amount of nitrogen needed to maintain *nitrogen equilibrium.* By this is meant that the intake of nitrogen equals the outgo. This seems to vary according to the amount ingested. If much nitrogen is taken in, much is eliminated. If little nitrogen is taken in, little is eliminated, so that apparently, nitrogenous equilibrium may be maintained with different amounts of nitrogen food. The quantity estimated for an average man doing a moderate amount of work, runs from 60 to 120 gm. of protein a day. With the maximum of 120 gm., go 90 gm. of fat, and 320 gm. of carbohydrates. A rough estimate for the proportionate amounts of food would be 1 part of protein for every 4 parts of fats and carbohydrates combined. A fairly generous protein intake seems to exert a stimulating effect upon metabolism in general.

Food in the body has to provide repair material for broken-down tissue, first. Even if no active work is done, mere existence destroys a certain amount of the structure. Protein *must* be supplied for this purpose.

Aside from the above, provision must be made to maintain the heat of the body. Protein, carbohydrates, or fats will supply this need. Their acceptability for the purpose varies. In the carnivora apparently unlimited amounts of meat may be utilized for every purpose, with the animal increasing in vigor. No disturbance of the functions of the kidneys is evident. In man an excess of protein burdens the excretory organs too much. From the experiments of the Arctic explorer, Stefansson, it appears to be possible for man to adapt himself, without injury to the organs concerned in the excretion of urea, to an exclusive meat diet. The use of fat as fuel might seem desirable, owing to its large caloric content. It is difficult to digest. Its metabolism is dependent on that of carbohydrates. For these reasons, it cannot serve as an exclusive source of heat. The carbohydrates are best adapted to this purpose. They oxidize readily, leaving no nitrogenous waste. Any one food used in excess excites the body to utilize it at the expense of the other two.

While an adult cannot store up nitrogenous material, in growing children part of the protein ingested goes to increasing the structure of the body. A similar result is seen during convalescence from illness. It is evident that children and invalids should have a larger proportion of protein than the normal adult. When growth ceases this need ceases.

In estimating the amount of food needed it is customary to allow 40 calories of food for each kilogram of weight in men, and 30 calories for women. A man weighing 180 pounds would have 3200 calories a day, and a woman of 120 pounds would have 1600 calories by this estimate. This assumes much less muscular activity for women than for men. Besides the elements of water, proteins, carbohydrates, fats and salts, required by the body certain other materials called "vitamins" are needed. An animal fed on the supposedly perfect combination of foodstuffs, that is, so much of pure protein, pure carbohydrate, and pure fat, will quickly fall ill, stop growing, if immature, and soon die. Experiments with animals showed certain elements lacking in such a diet, to which the name of "vitamin" was given.

Vitamins.—Vitamins have been isolated; they are contained in practically all natural foods, in very minute quantities. Their chemical composition is unknown as yet, though much research has been made. They do not produce energy of themselves but act as catalysts, influencing cell metabolism. The mineral salts cannot be utilized in the body if vitamins are absent. They have an important use in the formation of hormones.

In the partial or complete absence of vitamins many deficiency diseases develop, such as pellagra, beri-beri, scurvy, rickets, etc.

Vitamins are classified as they are soluble in fat or water.

Of the numerous substances of this nature five have been isolated, and given alphabetical names, A, B, C, D and E.

Vitamin A is fat-soluble, and has definite influence on epithelial tissue and nervous tissue. The wide-spread distribution in the body of epithelial tissue explains the skin disorders as well as the nutritional failure when vitamin A is deficient or lacking in the food intake.

Affections of the nervous system, as cramps of muscles, convulsions, lack of coördination occur, from the same lack.

Lessened resistance to infections, and impairment of sight, as "night blindness" also result from deficiency of "A."

Vitamin A is found in the fat of milk, fish, liver oil; fat of liver, and egg yolks. Such vegetables as carrots, tomatoes, sweet potatoes, yellow corn, alfalfa, clover and green vegetables contain it. Animals feeding on green vegetation store vitamin A in their livers. Heat does not destroy this vitamin.

Vitamin D.—This is fat-soluble. It is concerned with the proper balance in the blood of calcium and phosphorus. It also influences mineral metabolism in general.

It is claimed that there are many vitamins D, in fact, as many as there are sterols in the body.

The absence of "D" produces bony changes, as rickets, osteomalacia, etc.

Vitamin D is plentiful in fish livers, egg yolk, the fat of such fish as tuna, salmon, sardines, etc. The skin contains ergosterol. When the skin is exposed to natural or artificial sunlight, or the ultraviolet rays, this vitamin is developed, so it may be stored in the body. Various commercial foods, treated with ultra-violet rays develop vitamin D. This vitamin is destroyed by prolonged high temperatures and mineral acids, but is not affected by ordinary cooking.

It is possible to have too much of this vitamin

Vitamin E or X.—This is fat-soluble. It is claimed to be necessary in the food of an expectant mother to properly develop the child, and provide its natural breast food. It is found in the wheat germ, green food, olive and cotton-seed oil. Animals deprived of this may seem perfectly well, but are incapable of producing young. With insufficient amounts, the progeny is stunted in growth. Vitamin E is not destroyed by alkalis, acids, heat, light, or by oxidation. It has been suggested that vitamin "E" may be concerned in the metabolism of iron.

Vitamin "B."—This is water-soluble. It is a complex structure that has been divided into B^1 and B^2, with the probability that several other fractions will be sometime differentiated.

Vitamin B is essential to growth and carbohydrate metabolism. A deficiency of B^1 not only disturbs the above but also causes func-

tional, even degenerative, changes in the nervous tissues, together with nutritional changes as in beri-beri.

Among other elements vitamin B^2 contains a preventative of pellagra. B^1 is found in yeast, the seeds of plants, including grains, fruits, green vegetables, but not in milk.

B^2 is present in beef liver, kidneys, dried yeast, meat, egg-yolk, cabbage, and spinach.

Vitamin "C."—This is also soluble in water, and is often called the "antiscorbutic vitamin." It is necessary for the integrity of the blood-vessels through its action on the cement substance between the cells. It aids in establishing immunity to pathogenic bacteria. In connection with other vitamins it is concerned in calcium metabolism.

Deficiency or lack of "C" induces scurvy, as well as the lesser degrees of scorbutic symptoms.

Vitamin "C" is abundant in ripe fruits, such as the citrus family, tomatoes, and in germinating seeds. Carrots, bananas, apples and potatoes also furnish it. It is destroyed by high temperatures, bright light, and contact with some metals, as copper.

The functions of the various vitamins overlap, so that their associated action produces effects that otherwise would be impossible. It is difficult to exaggerate the importance of these elements in the human economy.

The Inorganic Mineral Salts.—Elsewhere, reference is made to the mineral constituents of the blood. These salts are necessary in the formation of the endocrine secretions; to the formation of enzymes; to the replacement of bone tissue; to maintain the proper balance in the blood between acidity and alkalinity, and some special uses as in the formation of hemoglobin, etc.

In natural, as compared with over-refined foods, there is apt to be a sufficient amount of these salts. Those most often lacking in quantity are calcium, phosphorus, iron and sodium.

Water.—Not less important than food is water. This must be regularly taken. Usually, some mineral salts are dissolved in water, but they are in less desirable form than those in the food, which are in such combinations as sodium chloride, calcium phosphate, etc.

All the water used in the body does not come from outside, as drink. Half as much comes from the food, and nearly one-half the latter amount by the oxidation of the food. It is eliminated by the kidneys as urine, through the skin as perspiration, from the lungs as watery vapor in the expired air, and a small amount passes off in the feces.

In general, the amount of water taken should be about 1500 cc., with a similar amount excreted as urine.

One other condition must be met, in this matter. The quantity of food which has an acid residue must be very much less than that which has an alkali residue. The "alkaline reserve" must be provided, because tissue cells cannot survive in an acid medium.

In general, meats, fish and cereals have an acid ash; fruits and vegetables produce an alkaline ash.

Roughage.—For normal movements of the bowels a certain amount of "roughage" is necessary. This is mainly "cellulose," the indigestible framework of fruits and vegetables, as well as the outer husk of grains. It adds bulk to the mass in the intestine, and so stimulates its activity.

METABOLISM.

The body uses food to maintain itself in existence, and to develop the various forms of energy, as heat, movement, thought, and secretion. The process by which the food elements in the blood become available for these purposes is called *metabolism.*

This may be considered as a series of chemical reactions by which the potential energy of the food is converted into the kinetic or actual energy of the body. It is also the process of building relatively simple materials into the complex constituents of the cells—the development of new materials therein, and the breaking down of complex substances into simpler ones which are subsequently eliminated as waste.

This divides metabolism into that of the cell (tissue metabolism) and that of the food materials (food metabolism) which takes place in the lymph spaces around the cells. In the cells the building-up process is called *anabolism.* The breaking-down is *katabolism.*

Ordinarily in health, the greater part of the metabolic activity is that of the food. Variations of this are due to the quantity and kind of food taken, the amount of exercise, physical, and mental, and the position of the body.

The metabolic process is comparable to the combustion of fuel under a boiler. Chemical changes, chiefly oxidative, occur with the development of heat, light, motion, or electricity.

When anabolism and katabolism are equal the body is in a condition of nutritive equilibrium, or it remains of the same weight, size and strength. When anabolism exceeds katabolism, as it should do during the years of the body's growth, the weight, size, and strength increase. When katabolism exceeds anabolism, as in starvation, the above three elements diminish. The organism calls upon the stored glycogen in the liver and muscles, upon the fats, and finally upon the built-up proteins for use in maintaining the body heat.

Metabolism During Starvation.—When no food is taken, desire for food passes away after a few days. The principal symptoms are

weakness, drowsiness, with a disinclination for activity. The pulse-rate and body temperature continue normal until near the end. The urine is diminished. A small quantity of feces is passed, consisting of disintegrated fat. There is a loss of weight, more or less constant. The stored glycogen is used up in a day or two; then the storage fat, to 97 per cent of its amount, after which the protein structures least necessary in carrying on respiration, heart beat, and conscious cerebration are disintegrated and taken up from the blood. As long as this is sufficient to maintain the body temperature, the animal survives.

As metabolism develops energy, and energy is manifested as heat, movement, thought, and secretion, if the latter three are limited, apparently only heat, in addition to the muscular activity required for the respiratory movements, and the contraction of the heart, is produced. That is, in the resting condition this minimal metabolism is all that is necessary.

It is found possible to accurately measure this heat production. The caloric equivalents of the various food elements being known, the amount of fuel used can be estimated from the amount of heat produced.

The machine used for measuring the heat produced is a "respiration calorimeter," in which the heat from the body warms a given amount of water to a certain degree. These machines are complicated and expensive, requiring highly skilled, expert manipulation. A modified apparatus is, therefore, more generally used, depending upon the heat equivalent of a definite amount of oxygen which may be consumed in respiration in a given time.

The activity of metabolism in health varies according to the muscular or mental activity, the position of the body, the time of day, the amount of food taken and the temperature. In pathological conditions there is much more variation, due to the presence or absence, of more or less, of the secretions of the ductless glands.

Basal Metabolism.—The measurement of tissue metabolism is usually made about 7 or 8 A.M. on an empty stomach, in the recumbent position and with the room temperature about 70° F.

This early hour gives the amount of tissue metabolism because no new food products are in the blood (since thirteen or fourteen hours have elapsed since the last meal), the waste products have mostly been carried away, and following the night's rest, the metabolic processes are at their lowest ebb. The term *basal metabolism* denotes this minimal condition. It is a fairly accurate measurement of the chemical changes taking place in the body cells.

The normal basal metabolism is calculated from the surface of an individual. With the height and weight known (the height in centimeters, the weight in kilograms), the formula multiplies

together W. times 0.425 by H. times 0.725, by 0.007184. The result is the surface in square meters.

According to DuBois, in adult males, the basal metabolism is about 40 Calories an hour for each square meter of surface. For women it is 37½ Calories. From thirty to seventy years of age the number of calories lessens at the rate of one for every ten years. At sixty, then, the basal metabolism should be 36. The comparison between the estimated normal and the amount shown by the test is of considerable value in many cases of metabolism disturbance.

As an animal fattens, the basal metabolism increases. The nutrition influences it, also. A person "reducing" can work as usual, using up fat. When the weight has lessened 12 per cent the basal metabolism lessens. Caloric requirements lessen, leaving just as much ability to work as before.

Protein Metabolism.—The food materials are metabolized in somewhat different ways, according to their chemical composition. In the digestive process proteins are transformed into amino-acids. There are, at least, twenty-one different amino-acids which appear to be selected by the different tissue cells for building according to their several needs. The amount so used varies being greater in immature animals than in those that are fully grown.

Part of these go into the large intestine, are subjected to bacterial putrefaction and break down into simpler compounds as indol, phenol, and skatol. Some of these pass off in the feces—the greater part of these proteins are absorbed, going to the liver where they are worked over into urea. A part of the amino-acids pass directly into the portal vein, thence into the liver, where they are converted into urea.

Some of these elements not needed by the cells are available for heat production by being metabolized outside the cells. To them the name "circulating proteins" is sometimes applied. They split up, forming carbonate of ammonia which enters into urea, and a compound of C, H and O, which is converted into CO_2 and H_2O with the development of heat.

Protein, taken as food, augments the exchange between O and CO_2. Some of the amino-acids have this power, due in both cases to stimulating the cells and increasing their metabolic activity.

The nuclei of meat cells taken as food undergo a breaking-up into guanin and adenin which subsequently gives rise to uric acid.

Fat Metabolism.—If a proper amount of fat is taken daily it is quickly transformed in the tissue spaces into its ultimate elements, CO_2 and H_2O, with the production of heat. If there is more than the body requires for maintaining the temperature and activity, the excess is stored away for future use—generally in regions where it is not likely to be disturbed by muscular activity.

There seems to be no limit as to the quantity of fat that can be

thus stored. Apparently it is laid down without having been changed.

Fat may also be formed from carbohydrate food which is in excess of the body need. These fats are deposited in the subcutaneous tissues.

Some of the end-products of protein digestion, the amino-acids, may be converted into carbohydrates. But it is still open to question whether fat is ever stored in the body from excess of protein food. The fact that many of the "fat-reducing" regimes include a diet composed mainly of meat, argues against the supposition.

Fat is not metabolized well if the carbohydrate metabolism is faulty. During fasting for weight reduction some carbohydrates must be taken, since one of the intermediate steps of the metabolism of fat results in the formation of *acetone*. Normally, this breaks up into CO_2 and water. If too much fat is taken this reaction is imperfect and the acetone is in excess. In order to dispose of this, with other acid products of the incomplete oxidation of fat, they must combine with alkaline substances in the blood and lymph before they can be eliminated by the kidneys. This is apt to result in a depletion of the alkali of the blood, causing an acid condition known as *acidosis*. A carbon dioxid poisoning, even death, may ensue.

The fat of the body when oxidized supplies heat and energy for muscular work. It may be converted into carbohydrates, just as carbohydrates may be converted into fat, according to the needs of the body.

Carbohydrate Metabolism.—The digested carbohydrates are temporarily stored in the liver and in the muscle cells as glycogen—a form of starch. They may be transformed back to sugar by an enzyme in the cells, and they must finally be oxidized to release their potential energy as heat or motion. Some of the carbohydrates are used to form lactic acid. If the carbohydrates are not oxidized they appear in the urine as sugar.

Some of the steps appear to be the conversion, by digestion, of starch and sugar into dextrose; absorption of dextrose into the blood which enters the liver; absorption of dextrose into liver cells and its conversion into glycogen. During periods of muscular activity the glycogen in the muscles diminishes, to be again increased during rest. In the blood there is normally found 0.08 to 0.10 per cent of sugar by the transfer of glycogen from the liver in the form of dextrose. If the sugar content of the blood falls much below 0.07 per cent, the person suffers severely with hunger, fatigue, and nausea, and may die. When this sugar passes into the muscle cells the percentage in the blood falls and the liver cells reconvert some glycogen into dextrose which goes into the blood, to replace the amount used by the muscles. During muscular activity intracellular enzymes are supposed to convert the contained glycogen

into dextrose with subsequent oxidation—the development of heat and motion, and the eventual release of CO_2 and water.

Numerous organs seem to be concerned in regulating carbohydrate metabolism. The secretion of the posterior lobe of the pituitary gland, the adrenals, the islands of Langerhans (insulin), all seem to exert an influence. Centers in the medulla also operate, as well as the hepatic plexus of the autonomic nervous system.

The islands of Langerhans in the pancreas secrete a material, *insulin,* whose function is to influence the metabolism of carbohydrates. The *destruction* of or injury to the cells is followed by the appearance in the urine of sugar. In normal conditions, the quantity of insulin thrown out is in proportion to the carbohydrate intake.

It appears that carbohydrates are essential to life. It also seems that in diabetics, or those with sugar in the urine, the liver and muscles fail to store glycogen. There is a rapid conversion of fats and proteids into carbohydrates, so that emaciation occurs in such diabetics. An excess of fat is in the blood and the liver. The blood sugar is greatly increased because of the failure of the organism to store it as starch, and of the increased amount available. Sugar is then excreted by the kidneys.

An amount of carbohydrate food in excess of the body requirement is apt to be stored as fat. This fat can be utilized for heat and energy production if the daily supply of carbohydrates falls below the body needs, or it may be reconverted into carbohydrate.

As long as the organism is alive, metabolism is more or less active. When it stops, death ensues.

The vigor with which metabolism is carried on measures the speed of living. A considerable degree of vigor is necessary to health. Various conditions influence metabolism. In hyperthyroidism, the process is much increased, with the reverse in a deficiency of the thyroid secretion. Exercise increases both anabolism and katabolism with consequent increase in the elimination of CO_2 and H_2O.

The nitrogen eliminated is also increased, but not markedly unless the carbonaceous food is insufficient to provide for the additional oxidation so that proteins have to be utilized to provide fuel. Then, the output of urea is increased.

During sleep the amount of nitrogen waste is about the same as when awake, but the CO_2 output is less.

Low temperature increases the output of CO_2, but not of urea, though it is claimed, no increase occurs unless shivering takes place. Shivering makes for increased muscular work, which increases oxidation.

Animal Heat.—The food we eat does more than provide for growth and repair. It furnishes the materials by which heat, motion, and thought are produced. Foods possess what is called "potential

energy," measured by calories, but the liberated energy may be in the form of heat, kinetic energy or secretion. The different forms of energy are interconvertible. All oxidative processes are accompanied by the development of heat, so the work of the cells results in heat or its equivalent. Only about one-fifth of the energy developed is in the form of mechanical energy or motion, so only one-fifth of the food taken results in muscular work. The rest of it goes to heat.

The force developed in this way is measured in terms of "grammeters." A *grammeter* is the amount of energy needed to raise 1 kilogram of weight a distance of 1 meter. Foster calls 150,000 grammeters a good day's work. This is roughly equivalent to a man weighing 180 pounds climbing a mountain 5000 feet high in a day.

Body Temperature.—If one "takes his temperature" with a clinical thermometer, he finds it to be essentially the same, morning, noon and night; whether the out-door temperature is 20° below zero, or 115° in the shade. The body temperature in man is 98.6° F. or 37° C., and this record persists in health regardless of the surrounding conditions. There is some wonderful mechanism to insure this, some means of regulating the body response to its environment.

Man is called a "warm-blooded" animal as distinguished from the frogs, fish and reptiles that are "cold blooded." These latter change their temperature with their surroundings, but man maintains a relatively high temperature regardless of that surrounding him.

It has been seen that the potential energy of foods becomes either heat or kinetic energy when oxidized in the body cell. According to the activity therein, more or less heat is secreted or thrown off from the glands and muscles. By joint friction, respiration, and cardiac activity, additional heat is produced.

Because of the great glandular activity of the liver, the highest temperature in the body is in the blood of the portal vein.

While the temperature of the body is always essentially the same, there is a small variation of a degree or so, in different parts of the body, at different times of day, and with different external temperatures. The temperature in the rectum is a degree higher than that in the mouth; that in the mouth is higher than in the axilla; the evening shows a higher temperature than the early morning; a surface exposed to the cold has a lower temperature than one that is protected. The blood in the liver is of much higher temperature than that elsewhere.

Heat production is called *thermogenesis;* heat loss is *thermolysis;* heat regulation is *thermotaxis.* By thermotaxis, thermogenesis is balanced by thermolysis, so the body remains at the normal temperature, and neither force runs wild.

It is supposed by some investigators that the thermotaxic nervous

center is in the *pons,* while the thermogenic center is lower. Others claim the *optic thalamus* is the center for heat regulation. The centers for thermolysis, as far as this is done by changes in the blood supply or the secretion of sweat, would evidently be in the medulla.

In fevers either thermogenesis may be increased or thermolysis diminished, causing a rise of temperature.

Muscular and glandular activity in making heat are governed by centers in the spinal cord. It is thought these centers maintain a fairly constant production of heat, but the higher centers in the brain may reflexly incite them to greater or less activity.

Heat is lost by various means. About 85 per cent is lost by radiation and evaporation from the skin. Some 12 per cent is lost in the lungs by warming the inspired air and by evaporation. A small amount is discharged in the urine and feces. Contact with colder objects abstracts heat from the body by conduction. Heat is lost more rapidly when the body is unclothed, as then the layer of dead air between skin and clothing is lacking.

Cold moist air and cold water contact lowers the temperature. A short cold plunge at first chills the body, driving the blood from the surface capillaries, but this is shortly followed by a reaction through reflex increased heat production.

Heat is lost when the internal temperature is raised and the external temperature is lowered. Its loss is greater in small bodies than in large ones, because the surface is relatively larger in small animals. This statement may be tested by computing the surfaces of a pillar, 1 foot square at the top and 2 feet high. The total surface will be 10 square feet A similar pillar, with a height of 4 feet, would have a total surface area of 18 square feet. The proportion of surface to contents is greater in the smaller pillar. Infants need more clothing for this reason than adults and larger children. As women have more subcutaneous fat, and fat is a poor conductor of heat, they can keep warm with less clothing than can men.

The greatest factor in equalizing heat production and heat loss is the blood. If a part is cold, more blood sent to it will increase its warmth. If the body surface is exposed to cold, as at 60° or less, the arterioles of the skin contract and the blood goes to the interior regions, where it will not be cooled. Shivering occurs, which by muscular activity promotes heat production. Between 60° and 70°, there is more or less blood in the skin, with the normal distribution between skin and internal organs at 66° to 68°. From 70° to 90°, more blood comes to the skin, the sweat glands become active and perspiration is induced with resulting evaporation which cools the surface. The effect of evaporation may be observed by placing a few drops of ether or gasoline on the skin and noting the chilling of the surface as it evaporates.

Nature goes to much trouble to ensure the regulation of the body temperature by automatic nerve centers which increase heat production when the surroundings of the body would injuriously lower the temperature, and inducing perspiration and evaporation when the outside temperature becomes higher, and liable to interfere with health. It is thus seen how important the function of thermotaxis is in the economy of the body.

QUESTIONS.

Define "calories."

Define "vitamins."

Define metabolism.

What quantity and proportions of the various classes of food are necessary in an average diet?

If much muscular work is done, which food element should be increased over the amount needed by a person engaged in a sedentary occupation?

What is "nitrogen equilibrium"?

How is the heat of the body maintained when the outdoor temperature is zero?

How is the body kept at a normal temperature when an outdoor thermometer reads 110° F.?

What is "basal metabolism"?

CHAPTER XIII.

THE ORGANS OF EXCRETION AND ELIMINATION.

THE metabolic processes of the body which include building-up and breaking-down produce a large amount of waste. These wastes are distinguished from the waste of the food which is thrown off through the rectum, having never really entered the body. The tissue wastes are in the blood stream, and must be eliminated through the mediation of the microscopic tissues.

The CO_2 is largely taken from the blood in the lungs, but the nitrogenous wastes, those produced by the breaking-down of proteins, are still to be disposed of. Incidentally, if retained this group of waste products, and there are many, is capable of doing much harm to the organism. The principal organs concerned in this elimination are the liver, kidneys and skin. The work done by the liver in forming urea has already been considered. This urea is thrown into the blood, and circulates through the body, but at each heart beat, a certain amount of blood goes to the kidneys, and there the further elaboration and elimination take place, with the subsequent ejection of the waste as *urine.*

The work of the kidneys is to maintain the normal composition of the blood, not only in respect to nitrogenous wastes, but also as regards salts, sugar, and water.

THE KIDNEYS.

The Anatomy of the Kidneys.—These two compound tubular glands, brownish in color, oval in shape, with a resemblance to a bean, are located about the level of the waist, or in the lumbar region, but they are *not* so low as in front of the sacrum.

They are behind the peritoneum, surrounded by a mass of fat and loose areolar tissue, which with the renal artery, vein and nerve help to prevent their downward displacement. The fascia covering the kidney is connected with the fascia of the quadratus lumborum and psoas magnus muscles, and with these to the aorta. The pressure of surrounding organs is another factor in holding the kidneys in place.

The upper border is on a level with the upper border of the twelfth thoracic vertebra, while the lower border is level with the third lumbar vertebra. The right kidney is a little lower and wider than the left. They are about 4½ inches long, 2 inches wide and 1½ inches thick. The weight varies from 4½ to 6 ounces. Covering the kidney is a

fibrous capsule which continues from the outer surface to the pelvis of the kidney lining it, as well as the infundibula and the calyces. On the inner and forward part is a depression, called the *hilum*, from which arise the *ureters*, and through which pass the renal artery, vein, and nerve. (Fig. 302.)

On cutting the kidney lengthwise, it is found to be of a dark red color, with pyramidal spaces of lighter red. (Fig. 303.)

The outer border is the cortex or medullary portion with the pyramidal portion toward the center. The latter opens into a cavity, called the *pelvis of the kidney*, from which also emerge the *ureters* or excretory ducts of the organ. Three short canals from the pelvis go toward the upper, middle and lower parts of the kidney. These are *infundibula*. Each divides into several smaller canals called *calyces*, which receive the apices of the pyramids.

The cortical layer, about $\frac{1}{6}$ inch thick is of a reddish granular structure. It contains the essential, secreting portion of the kidneys, the *glomeruli* (Malpighian corpuscles), with the convoluted tubules, blood-vessels, and lymphatics imbedded in areolar tissue.

The Blood Supply of the Kidney.—The kidneys receive their blood supply through the *renal* arteries. These enter at the hilum and divide into numerous branches. Those going to the cortex take part in the secretion of urine.

The Glomeruli.—The arterioles enter capsules, called Bowman's capsules, formed by the folded-in-ends of renal (uriniferous) tubules. Here they wind into tufts, snarls, or skeins, without forming a network. Emerging from the capsule, the arteriole passes down and breaks up into a capillary network around the convoluted part of the tubule. From this network the venous capillaries emerge, uniting to form the renal veins at the hilum, eventually going into the inferior vena cava. (Fig. 304.)

Uriniferous Tubules.—They begin as invaginated ends of tubes. When they leave the glomeruli (capsules) they take an extremely tortuous course, finally opening into the apices of the pyramids at the end of a straight portion of the tube.

The uriniferous tubules consist of epithelial cells on a basement membrane. These cells are mostly nucleated and secretory. The tufts of capillaries are covered by, and Bowman's capsule is lined by, delicate endothelial cells through which the blood plasma readily passes.

The Physiology of the Kidneys.—The diagram (Fig. 304) should be studied as an aid in comprehending the way in which the urine is secreted.

Mechanism of the Formation of Urine.—Because the caliber of the arteriole on leaving the glomerulus is less than it is on entering it, the supposition is that the blood-pressure therein is higher than it is outside the tuft. This produces a filtering effect in which water

and soluble mineral salts from the blood pass out into the renal tubule. In the convoluted portion of the tubule the epithelial cells take the urea, creatinin, uric acid, phosphates, etc., from the blood and send them into the tubule, where they are dissolved and carried along. Possibly, some of the water is reabsorbed as it passes along the extremely long tubing, thus increasing the specific gravity of the urine that has been formed. The flow of urine is increased by an increase in the blood-pressure, and *vice versa.*

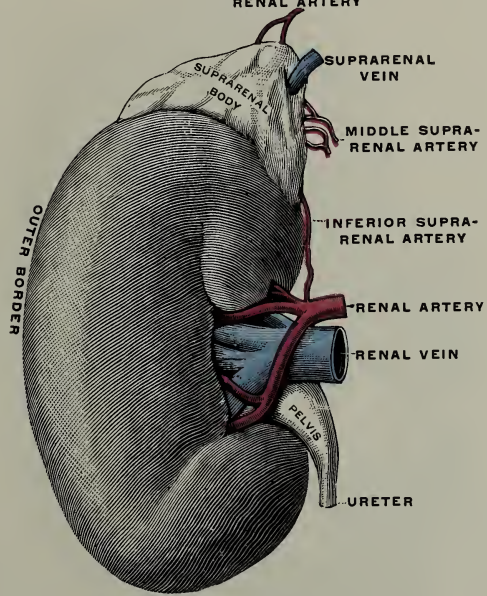

FIG. 302.—Right kidney, ventral aspect. (Testut.)

The Malpighian corpuscles are from $\frac{1}{250}$ to $\frac{1}{100}$ inch in diameter. The renal tubules are from $\frac{1}{2000}$ to $\frac{1}{200}$ inch in diameter.

From the blood the route of the urine is, through the glomeruli, the convoluted tubules, the straight tubules, the calyces, the infundibula, to the pelvis of the kidney. Thence through the ureters to the urinary bladder and out through the urethra.

The Urine.—Urine is a fluid of light yellow color, acid reaction, specific gravity of 1020, and amounting in twenty-four hours to 1500 cc. Among its constituents are: Urea, uric acid, chlorine, phosphoric acid, sulphuric acid, creatinin, hippuric acid, oxalic acid, several nitrogenous acids, fatty acids, dissolved nitrogen and carbon dioxide, pigments, as urochrome and urobilin. With the possible exception of hippuric acid and ammonia, all these materials are formed in parts of the body other than the kidneys.

Under pathological conditions, sugar, albumin, bile, hemoglobin, acetone and other substances may be present.

The composition of urine varies according to different conditions of nutrition, exercise, sleep, age, sex, diet, respiratory activity, condition of skin and emotions.

The principal ingredient is urea, which is found in the blood at all times. A certain percentage is always present, and if the kidneys function properly, all in excess of this normal amount is removed

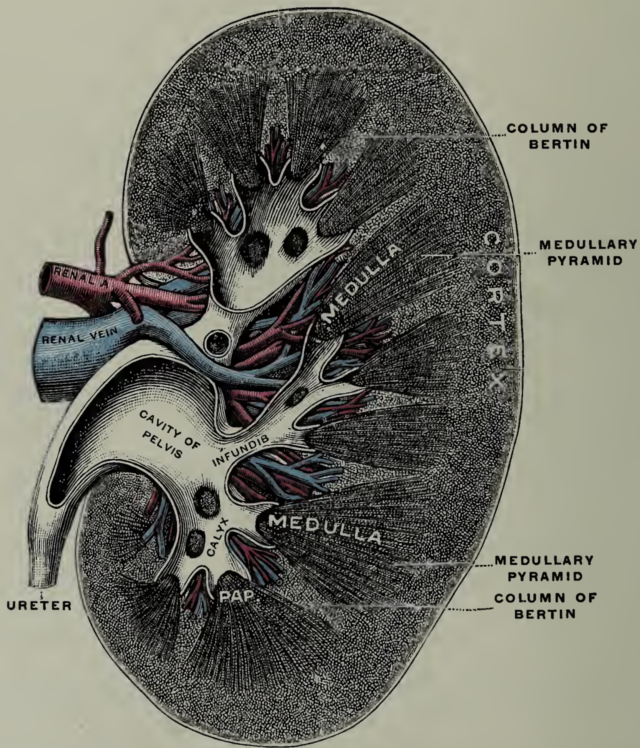

Fig. 303.—Vertical section of kidney, showing the secreting portion, the vessels and the beginnings of the ureter. (Testut.)

The presence of urea in the blood seems to be the stimulus which excites the activity of the epithelial secreting cells. It is considered probable that the secretion of the posterior lobe of the pituitary body is influential in regulating the activity of the kidneys. The greater the amount of blood with its contained urea that passes through the kidney, the greater the activity of that organ.

The amount of blood that passes through is influenced by several factors.

1. External temperature. Cold sends the blood from the skin to the interior organs, while heat reverses the process.

2. By the amount of water ingested. The more water, the more urine.

3. By the amount of protein food. (An excess of protein beyond the needs for repair or building must be eliminated.)

FIG. 304.—Diagram of Malpighian corpuscle and uriniferous tubule, with arteriole forming a snarl or intricate loop in the beginning of the tubule.

This arteriole does not break up into a network in the corpuscle, but after leaving the latter forms a capillary network around the convoluted tubule.

From these capillaries the venous radicles arise, which, uniting, eventually form the renal veins.

4. By nervous excitement. This increases the amount of urine, but lowers the percentage of solids.

5. By muscular activity. The greater the tissue metabolism, the more urea is formed and eliminated.

6. By the amount of perspiration. Excessive perspiration carries off much of the water and salts of the blood, lessening the amount of urine.

7. During sleep the amount of secretion is lessened, being at its minimum between 2 and 4 A.M.

After the urine collects in the pelvis of the kidney it passes into the *ureter,* a tube about 18 inches long which goes to the urinary bladder. It penetrates the bladder obliquely, so if the bladder becomes distended the opening from the ureter is automatically closed, and regurgitation to the kidney prevented. As the middle coat of the ureter is muscular, a peristaltic wave carries the urine along, regardless of the position in which the body is placed.

The Nerve Supply of the Kidneys.—The kidneys are controlled by the autonomic system. Through the lesser splanchnic nerve the preganglionic fibers pass into the renal ganglion, from which emerge the postganglionic fibers to form the renal plexus. The secretory and vasomotor fibers are supposed to be regulated by a center in the medulla, though there may be other centers in the lower part of the spinal cord.

THE BLADDER.

This is a reservoir for urine, where it is retained until it is convenient to expel it. It is ovoid in shape, holds about a pint, and is located in the front part of the pelvic cavity.

There are three coats, the outer of peritoneum, the middle of plain muscle fibers, and the inner of mucous membrane. The muscular coat is in three layers, with the fibers running in various directions. When it contracts the contents of the bladder are compressed in all directions.

The outlet of the bladder is embraced by a thick band of unstriped muscle tissue, the *sphincter vesicæ.* This is usually in tonic contraction, so preventing the involuntary escape of urine. When the bladder has become moderately full, the desire to expel its contents arises. The act of expelling is micturition, and involves the relaxation of the sphincter, the contraction of the muscular wall of the bladder, aided by the contraction of the abdominal wall. A slight contraction of the abdominal wall compresses the bladder, and the relaxation of the sphincter allows the urine to pass out.

The *urethra* is a short tube that leads outward from the bladder.

The nerve center for the bladder is in the spinal cord, in the lumbo-sacral region.

THE SKIN.

The third apparatus for the elimination of tissue waste, and which may act vicariously for the kidneys, is the skin.

The skin or integument is the external covering of the body, varying in color, texture, and thickness. According to the amount of pigment, the color varies from milk-white to black, mahogany, yellow, or brown. It varies in texture from a satiny smoothness to a coarse horny roughness. In thickness, it varies from $\frac{1}{12}$ to $\frac{1}{2}$ inch.

It has furrows everywhere, which differ in character in different individuals, so that the markings of the thumb, for instance, serve for identification.

The structure of the skin is in two parts, the corium or true skin, or cutis vera, and the epidermis, scarf skin, which is external to the former. The *corium* is the active part of the skin, and is very complex. External to, and connected with, the superficial fascia is a network of areolar tissue, which allows the skin to move freely on the underlying parts, serving as a bed for numerous organs. In this bed are the branchings of the arteries, veins, and lymphatics that supply these parts and drain them. An abundant blood supply is evidenced by the fact that it is impossible to pierce the skin anywhere without drawing blood. Scattered through the areolar tissue is its specialized form, adipose, as masses of fat, in varying degree, but always present.

On the summits of the furrows are elevations, called papillæ. (Figs. 305 and 306.) In the papillæ are the end-organs of the sense of touch, or Pacinian corpuscles (tactile corpuscles). The tactile corpuscles are laminated like an onion, with from forty to sixty coats. The nerve fiber penetrates to the middle of this bulb, and finally ends in bulb-like processes. They are thickly scattered on the skin, with very few areas without them. The endings of the sensory nerves vary in structure, and it is possible that there are different ones for the sensation of heat, cold, pressure, and pain.

The tactile corpuscles differentiate various touch sensations. For instance, a small bit of steel dropped on the skin might feel cold, but give no sensation of weight. When this bit of steel becomes warmed by the skin it is no longer sensed as being on the skin. A larger object of the same temperature as the skin would give the sensation of weight or pressure only. A sharp object pressed on the skin would cause pain. A few straggling hairs would tickle. A drop of acid would sting. We recognize pain, pressure, and temperature sensations.

These various sensations are not necessarily evident at the same spot, nor at every spot on the surface of the skin. Certain areas fail to register one or more of these sensations.

Cold objects will affect definite areas which may be mapped out on the skin. They are not identical with those responding to heat. It is stated that the temperature sense is most marked on the flexor surface of the arm and forearm, on the abdomen, the chest, nipples, and nose. If the skin is very cold or very hot the discrimination between heat and coldness is blunted.

The pressure or touch sense enables us to judge of size, shape, texture, and quality. This sensation arises from a displacement of the skin. Pressure on all sides of a finger gives no sensation

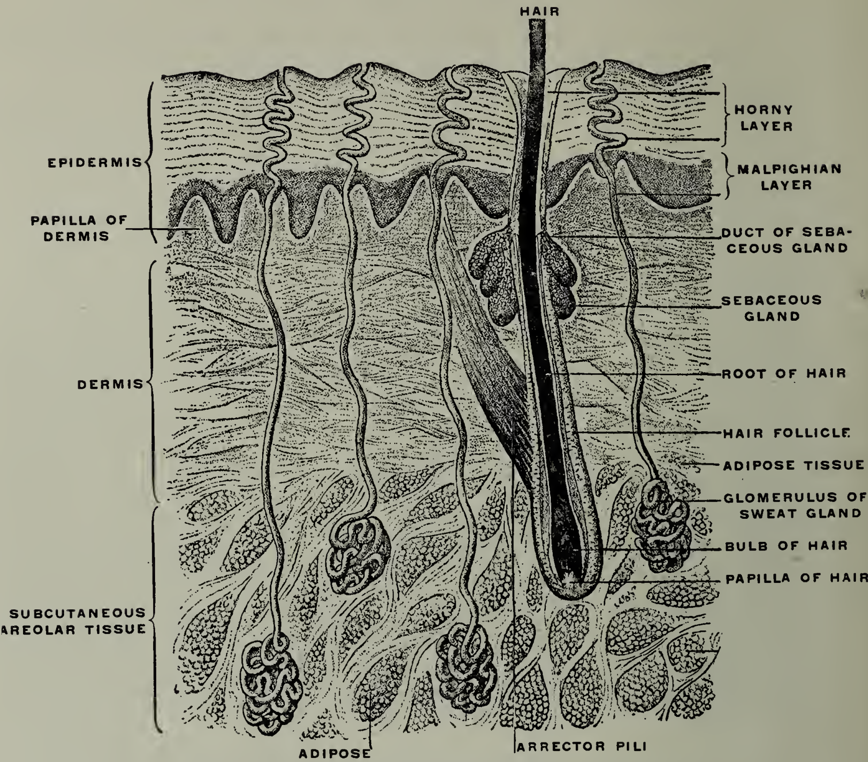

Fig. 305.—Vertical section of the skin. (Testut.)

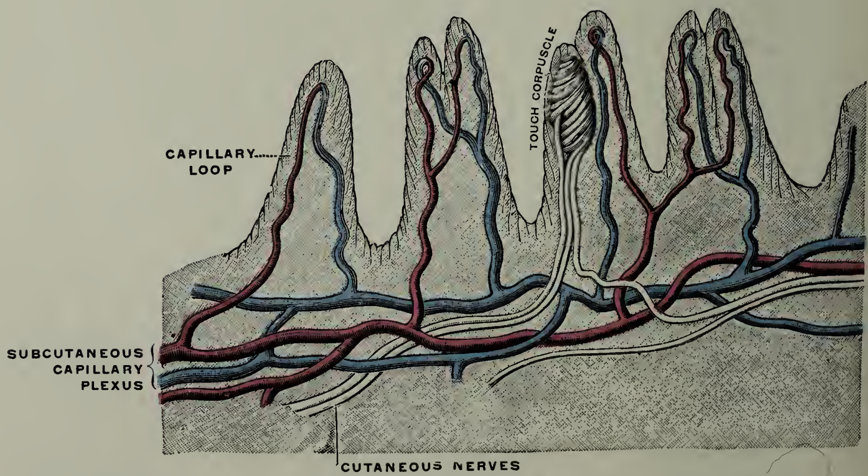

Fig. 306.—Papillæ of the skin, showing the arrangement of the vessels and nerves. (Testut.)

as there is no displacement of the skin. The tactile sense recognizes stimuli that come at the rate of 500 or 600 per second, as being separate. The sense rapidly becomes so accustomed to a given stimulus that it fails to register.

Around the root of each hair is a plexus of nerve fibers. Any stimulus to a hair is augmented many times. Thus, a mosquito lighting on the hair of the head creates much more commotion than in lighting on the shoulder.

The sense of touch discriminates as to locality. If two points are stimulated at the same time, unless there is a certain distance between them, the sense report is one touch. The distances necessary to register as two points vary in different parts of the body. The mobility of a part makes a difference as to this discrimination. The finger tips are more than twenty-five times as acute as the shoulder.

Closely allied to touch is the sensation of pain. Pressure sufficiently increased causes pain. Hilton's book on the *Value of Rest and the Significance of Pain* shows this sense as a defense of the organism and a warning of pathological processes taking place. Many different kinds of pain are recognized, as sharp, dull, aching, heavy, sickening, burning, boring, etc. Certain spots on the skin make no response to what are painful impressions elsewhere. Certain spots register only pain. Some areas respond to touch sensations but not to those of pain.

Fig. 306 shows the capillary loops in the papillæ from a network in the cutis vera. Branches go to the fat, sweat and sebaceous glands.

Epidermis.—The second part of the skin is the epidermis or scarf skin, or cuticle. Two strata, the Malpighian layer and the horny layer, *stratum corneum,* arise from a single layer of columnar cells resting on the corium. The Malpighian layer consists of some four layers, the layer of parent cells above mentioned, then polyhedral prickle cells, with pigment, overlaid by granular cells, and a series of transparent cells, called the "stratum lucidum." These are all nucleated cells, and the upper layers become merged with those of the horny layer which lose their nuclei, become scale-like at the surface and are shed.

The bed of the nail is a part of the Malpighian layer.

Sweat Glands.—The sweat glands are true excretory organs in the skin, to the number of 2,500,000, as estimated. They are tubular glands, coiled up at the inner end to provide greater secreting surface, and as the pores opening on the surface of the skin. The coiled tube is lined with columnar epithelial cells, which take from the blood, water, and various salts, sodium chloride largely, and some urea and uric acid, etc. The sweat is more or less profuse according to circumstances, but an average amount is over 2 quarts

in twenty-four hours. Even when the outer temperature is at 70° F. or less, there is a constant slight activity of the sweat glands, producing "insensible perspiration."

Sweat is salty in taste, of acid reaction, and characteristic odor. By the secretion of visible perspiration and its evaporation, the surface of the body is cooled, and its temperature lowered. This occurs when the external temperature is 70° F. or more, or when the skin temperature is increased by muscular exercise.

An occasional person has been found in whom the sweat glands were lacking, necessitating the use of external applications of water when the body temperature threatened to rise unduly.

Secretory nerves from the sympathetic rami communicantes are distributed to these glands. The control seems to be automatic from the medulla.

The temperature of man is 98.6° F., or 37° C., which is higher than that of the outside air, in most cases. Heat is lost all the time by radiation, convection, and conduction. The extent to which fat is present subcutaneously modifies the loss of heat, as fat is a poor conductor. Clothing, by interposing one or more layers of dead air between the skin and the air, prevents heat loss. Vigorous muscular exercise causes an increased blood supply to the skin, which makes up for any heat loss by radiation.

It is in the reduction of heat that the skin is most directly useful. As stated above, with an external temperature above 70° F. the sweat glands secrete visible amounts of sweat, which by evaporation cools the surface.

In fever the decline of the temperature is ushered in with more or less general sweat.

The Hairs.—Except for a few areas, the whole skin is studded with *hairs*, varying from a fine down (lanugo) to the stiff hairs of the eyelashes and beard. They vary much in length, thickness, and coloring. Straight hair is cylindrical on cross-section, while curly hair has flat places which cause the curves. A hair consists of a shaft, and the root or bulb. The bulb of the hair is whiter and softer than the shaft, and is lodged in an involution of the epidermis, called a follicle. The bulb contains various epithelial cells, some of which contain pigment, which gives color to the hair. (Fig. 305.)

The structure of the follicle is rather elaborate, and the shaft of the hair only less so. The shaft consists of a central pith or medulla, a fibrous covering, and an external cuticle of imbricated scales. In the fibrous portion, between the cells, are pigment granules in dark hair, or air spaces in white hair.

Passing between the surface of the corium and the follicle are small muscles which by their contraction erect the hair. The bristling of hairs on the back of a dog's neck when he is angry shows their action more vividly than is possible in human beings.

Sebaceous Glands.—Opening into the hair follicles are sebaceous glands, compound racemose in form which secrete oil, serving to prevent dryness of the hair and skin. These glands are also in various other places where little hair is found, as on the nose and eyelids (Meibomian glands).

Nails.—Modifications of the epidermis, or appendages of the skin are the nails. The body of the nail is translucent, showing the blood beneath, except at the upper end where a half-moon shaped area, the *lunula* is more opaque. The free edge of the nail overhangs the end of the toe or finger. The root of the nail is imbedded in a groove of the skin, while the nail-bed holds the nail closely adherent. The proximal part of the bed is the *matrix,* at which growth takes place, requiring some three months for a complete new nail to grow to the free edge.

Functions of the Skin.—The skin is a protective organ, preventing the escape of fluids, as the blood and lymph, serving to prevent injury to the sensitive underlying parts, the entrance of foreign material, bacterial or otherwise, and, by means of the pigment, shielding the sensory nerves. It is a sense organ, serving the sense of touch. Through the sweat glands it helps to regulate the heat of the body. Through the sweat glands the skin can throw off much of the nitrogenous waste of the body, serving vicariously for the kidneys when the latter are unable to function. It is a matter of common knowledge that when the body perspires freely the secretion of urine is lessened in amount, and conversely, when the surface is chilled, so perspiration is checked, the amount of urine is increased. In blondes, the lessened amount of pigment in the skin renders them susceptible to strong sunlight.

Absorption Through the Skin.—The skin, when uninjured, does not absorb any watery solutions. A certain amount of absorption of material dissolved in some fat does occur. Cocoanut oil seems to have more penetrating power than any other substance. If the scarf skin is rubbed off, absorption of various substances will occur.

QUESTIONS.

What is urea? What is urine?

Locate the kidneys. What is their function?

How does the kidney function compare in importance with that of the stomach?

What are the functions of the skin?

Describe the "cutis vera."

Where are Pacinian corpuscles found?

CHAPTER XIV.

THE SYMPATHETIC OR AUTONOMIC NERVOUS SYSTEM.

In Chapter VII, the consideration of the nervous system of the body was begun by the study of the cerebrospinal division. This has to do with controlling the muscular system, and with the special senses.

It has been observed that the muscles of the skeleton are controlled by nerves from the brain and spinal cord, with the axones coming directly from the neurons of those regions. They have no independent action, but their movements are initiated either as a reflex from some external agency or through the will.

There remains now, to consider the second division of the nervous system, known as the autonomic or sympathetic. This is concerned with the reflex control of bodily functions by which the organism is kept alive, or with the so-called vegetative functions.

All the involuntary or smooth muscle fibers in the walls of blood-vessels and in those of the hollow viscera in the body are governed by the sympathetic. All the epithelial cells in glands or viscera have fibers from this system to control their activity.

Various names have been used to describe this portion of the nervous system, as the involuntary, the vegetative and the visceral. The present preferred nomenclature seems to be to divide the autonomic into *sympathetic* and *parasympathetic*.

Location.—The sympathetic consists of ganglia and neurons forming cords connecting the ganglia.

(A *ganglion* is a pinkish-gray mass of neurons, with cells, dendrites, axones and blood-vessels enclosed in a fibrous capsule. The cells, also, have fibrous capsules, from which a coating extends over the axones.)

There are three groups of ganglia.

On each side of the front of the spinal column is a chain of ganglia, extending from the base of the brain to the coccyx. These are the *vertebral ganglia.* While there are thirty-one pairs of spinal nerves, these number twenty to twenty-three.

Three pairs of ganglia, the superior, middle and inferior cervical are in the neck; 10 or 11 are in the thoracic region; and the rest are in the lumbar and sacral region, with a single ganglion in front of the coccyx (ganglion impar).

The ganglia are connected by the gangliated cord which extends from the superior cervical to the ganglion impar, making an appearance like a chain of beads with a pendant.

The superior cervical ganglion is connected with the four upper cervical nerves which form the cervical plexus, and with several cranial nerves, including the vagus. It sends filaments to the upper cardiac nerve; also vasoconstrictor fibers to the blood-vessels; secretory fibers to the salivary and sweat glands; and fibers to dilate the pupil. (Note its relation to the suboccipital muscles.)

The middle cervical ganglion connects with the fifth and sixth cervical spinal nerves, and with the superior and inferior ganglia. It sends branches to the thyroid gland and to the upper cardiac nerve.

The inferior cervical ganglion connects with the middle ganglion, the seventh and eighth cervical and unites with the first thoracic ganglion to form the *stellate* ganglion. From this ganglion passes stimulatory fibers to the heart with vasodilators to the coronary arteries. When the heart is called upon for extra work, increased blood supply goes by dilating these arteries. (Fig. 308.)

Physiologically, the cervical sympathetics are very important, and a careful study of their relations to surrounding and distant structures is necessary for those engaged in physio-therapeutic work. It is particularly desirable to study the effects produced through them by excessive muscular tension of the back of the neck.

From the cells of the lateral horns of the gray matter of the spinal cords, from the second thoracic to the third lumbar vertebra fine white medullated fibers pass outward along with the anterior nerve roots, and sooner or later these fibers arborize around the cells in a sympathetic ganglion. These fibers are called "*preganglionic* fibers or *white rami communicantes*. (Fig. 215.)

The Splanchnic Nerves.—Certain preganglionic fibers are grouped together. From the fifth to the tenth thoracic segments, they become the *greater splanchnic nerve*. From the ninth and tenth thoracic comes the *lesser splanchnic*, while the *inferior splanchnic* is derived from the second and third lumbar segments.

From the ganglion cells, non-medullated fibers emerge as *postganglionic*, or *gray rami communicantes*. They pass to the *peripheral* ganglia from which axons supply epithelial gland cells; non-striated muscles in the walls of the blood-vessels; muscles in the walls of the hollow viscera, and the sweat-glands of the skin. (Fig. 308.) These fibers are the *rami viscerales*.

By this means, the greater splanchnic nerve connects the spinal nerves with the semilunar and superior mesenteric ganglia; the lesser splanchnic connects them to the renal ganglia, and the inferior splanchnic with the inferior mesenteric. These ganglia are called the *peripheral* or prevertebral.

Other peripheral ganglia are the *ophthalmic,* back of the eyeball; the *sphenopalatine,* at the base of the brain; the *otic,* below the *foramen vestibuli* (between the middle and internal ear); the *submaxillary,* near the salivary gland of that name; the *cardiac,* in the walls of the heart; the *plexi of Meissner* and *Auerbach* in the walls of the stomach and intestines, and the *pelvic,* near the base of the bladder.

In the thoracic region white preganglionic fibers come from the spinal cord and communicate with ganglia on the same level, or turn upward or downward to those on other levels.

The fibers in the upper thoracic region communicate with the cervical ganglia, and so influence the heart action.

By these means the fibers from the thoracic and lumbar spinal cord become associated with all the vertebral and prevertebral ganglia. The gray rami that arise in the cells of these two sets of ganglia enter the cerebrospinal nerve trunks, going with their motor and sensory divisions to the walls of the blood-vessels, the sweat glands, the thyroid, the adrenals, etc., and serve as inhibitory nerves to the muscles of the hollow viscera.

The visceral fibers which arise from these ganglia go to the epithelial cells of the viscera in the thorax and abdomen.

Besides the above collections, each organ has one or more groups of cells within its substance, which influence its activity, even when shut off from the other two groups. They seem to work automatically and with a rhythm peculiar to each organ. These are called *sporadic or intrinsic.*

As the cells from which the preganglionic fibers emerge cannot originate impulses, there must be some outside influence to initiate activity. This influence is generally reflex, as in the case of the smell of food exciting the secretion of saliva, or through emotions. This latter is shown by the change in the rhythm of the heart by the emotion of fear or anger. The pressure of food in the stomach by which the gastric secretion is increased, is an instance of a sensory impulse from without initiating activity. The varying chemical composition of the blood may also start activity.

It thus appears that the activity of this part of the nervous system is, in the main, reflexly excited, with modifications by various emotional impulses.

The *parasympathetic* division of the autonomic nerves consists of fibers from three parts of the cerebrospinal axis—namely, the midbrain, the medulla and the second, third and fourth sacral nerves.

The fibers from the mid-brain go out through the oculo-motor nerves to supply parts of the eye.

Those from the medulla pass by way of the seventh, ninth and tenth cranial nerves to the salivary glands, the cranial mucous membranes; to the walls of the blood-vessels, the heart and the

bronchi. Those fibers in the vagus supply the stomach, liver, pancreas, intestine and kidneys.

The fibers from the sacral region pass by way of the pelvic nerve to the colon, the rectum, the bladder and the genital organs. (Fig. 308.)

(A careful study of Figs. 214 and 308 will enable the student to understand these main facts in regard to the sympathetic and parasympathetic. Note the extensive distribution of the fibers contained in the vagus nerve. The blue lines in Fig. 308 indicate the parasympathetic.)

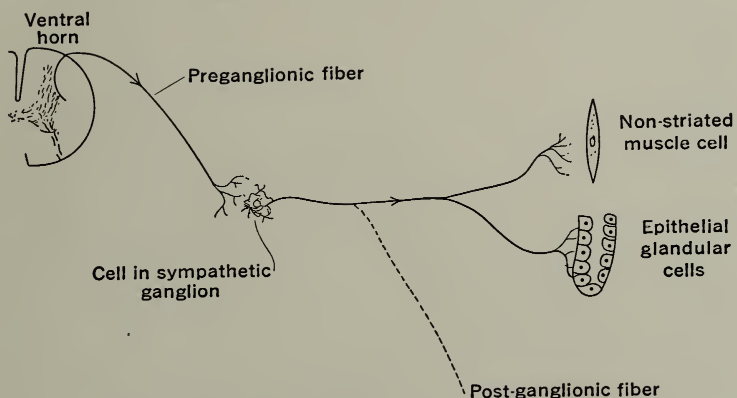

Fig. 307.—Diagram showing connection of cerebrospinal and sympathetic nerves.

In association with the efferent fibers, as above, there are afferent or sensory fibers which carry sensations from the thoracic and abdominal organs. In health very little cognizance is taken of reports from these viscera, but in pathological conditions these fibers may carry impulses which register in the sensory areas of the cortex as extreme pain. Such sensations from the abdominal organs are apt to depress the psychic centers much more than the same amount of pain elsewhere.

Fear, anger and other emotions, mediated in the brain have definite effects upon the various organs. Fear blanches the skin. weakens the muscles, especially the extensors, and changes the rhythm of the heart. It may stop digestion midway. Fear is a mental emotion, located in the sensorium, but working out through the blood supply of these various parts.

Relation of the Sympathetic System to the Functions of the Body.—Under normal conditions it is supposed the autonomic nerves are always excited reflexly and involuntarily. Sensory impressions that initiate the reflexes are visual, auditory, olfactory, gustatory, pressure, temperature, pain, hunger, thirst, etc. The response that completes the reflex may be excitatory or inhibitive. The excitatory response may be either motor or secretory. The motor responses

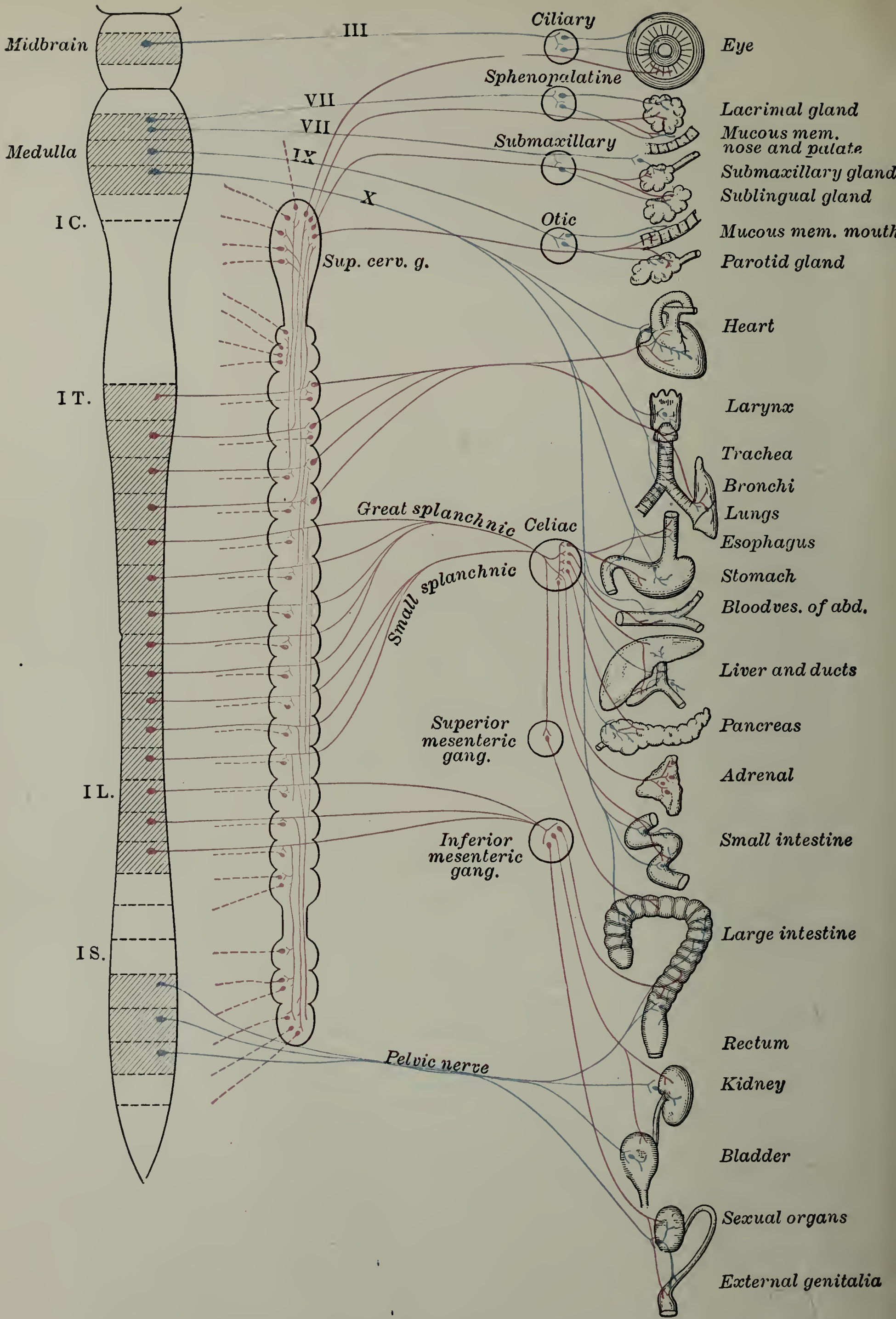

FIG. 308.—Diagram of efferent sympathetic nervous system. Blue, cranial and sacral outflow. Red, thoraco-humeral outflew. ------, postganglionic fibers to spinal and cranial nerves to supply vasomotors to head, trunk and limbs, motor fibers to smooth muscles of skin and fibers to sweat glands. (Modified after Meyer and Gottlieb.)

may be in the sphere of the vasomotor, cardiomotor, or visceromotor phenomena.

The secretory response may be the production of the salivary secretion, gastric juice, pancreatic juice, bile, urine, sweat, etc. Or the response may be to inhibit motor or secretory activity.

Specifically, through the efferent fibers certain familiar phenomena occur.

The ophthalmic ganglion is in relation with the motor oculi muscle through connecting fibers. Its postganglionic fibers increase the tone of the sphincter muscle of the iris, regulating the size of the opening and the amount of light admitted to allow the perception of clear and distinct images.

The sphenopalatine ganglion is in relation with the facial nerve. Postganglionic fibers go to the lachrymal gland, inhibiting the constrictor muscles of the arterial supply, so allowing an increased amount of blood, and also stimulating the secretion of tears. As the facial is the nerve of emotional expression, it is easy to see the connection between sad emotions, their facial expression and tears.

Another postganglionic fiber goes from the above ganglion to the mucous membrane of the upper part of the respiratory tract, inhibiting the circular fibers, so increasing the amount of blood in the membrane, at the same time stimulating the epithelial cells to secrete mucus. It is said that there is no local control of the blood-pressure in the cranium, but that it is dependent upon the general vasomotor control. If cold strikes the skin the vasomotor muscles are stimulated to contract, so driving the blood from the skin to the interior. This frequently results in stimulating the kidney function.

The glossopharyngeal nerve comes into relation with the otic ganglion, and the postganglionic fibers act to increase the secretion of saliva. Hence, the taste of food starts or increases the secretion of saliva to digest it.

The vagus nerve comes into relation with the ganglia in the walls of the heart, stomach and intestines. The postganglionic fibers from these ganglia inhibit the tone of the heart muscle and its power, so slowing the action of the heart. By inhibiting the contraction of the muscles in the wall of the esophagus at its lower end, the food is allowed to pass into the stomach. Secretory fibers are sent to the gastric glands. There is an increase in the contraction of the muscles in the walls of the bronchi, and of the stomach, and intestines, etc., through their connection with the vagus.

Through this slowing or inhibition of the heart the serious effect of a blow over the solar plexus may be explained.

The Solar Plexus.—A little below the diaphragm is an aggregation of nervous tissue called the *solar plexus* or *abdominal brain.* Fibers from the vagus, the greater and lesser splanchnic nerves, the semilunar and superior mesenteric ganglia take part in its formation. It

controls the vasomotor, secretory and motor activity of the abdominal viscera.

The preganglionic fibers from the segments of the cord below the fifth dorsal are related to the semilunar, renal, superior mesenteric ganglia, etc., and from the neurons leaving these ganglia, fibers, as vasoconstrictors, go to control the bloodvessels of the spleen, kidneys, liver, stomach and intestine.

It should be observed that there is an intimate relation between the tonus of the skeletal muscles in a given region, and the tonus of the visceral muscles in the same region. Consider the relationship between bad posture and poor digestion from this standpoint—the flaccid muscles in the scapular regions and in the abdominal wall and the reflection of weakness in the organs concerned in digestion.

The postganglionic fibers in relation with the lumbar and sacral nerves (the region from which the great sciatic emerges) influence the contraction or dilatation of the bloodvessels of the skin over the lower extremity and control the secretion of sweat in that region. (Fig. 308.)

The Subconscious Mind.—The study of psychology and physiology meet in the consideration of the subconscious mind. What the conscious mind is to the cerebrospinal nervous life, the subconscious is to the sympathetic realm, or vegetative life. There is a widespread belief that the conscious mind can influence if not control the subconscious mind by means of suggestion; either from one's self or through another. The explanation of the wonderful apparent results of the mental science or suggestion methods depends upon the fact that the control of the vital processes of life, respiration, circulation, digestion, assimilation, etc., are through the subconscious mind and its sympathetic servant.

QUESTIONS.

How does the autonomic part of the nervous system differ from the cerebrospinal portion?

In what way are the spinal nerves connected with the sympathetic ganglia?

How would you explain the phenomenon of blushing?

How is the amount of blood going to the stomach regulated?

Make a diagram showing the way sweat on the palms is produced.

What are rami communicantes?

What is known as the parasympathetic division?

CHAPTER XV.

THE DUCTLESS GLANDS.

Reference has been made to *internal secretions* or those which are made by glands and pass out into the blood stream, as compared with those that are carried off through a duct, or the *external secretions*. It has been relatively easy to study the latter, experiment with them in laboratories, and determine their function with a fair degree of probable accuracy.

The study of internal secretions has been attended with much difficulty, and is still far from being complete. By removal of a gland it has usually been found that its secretion was essential to life. If only partially removed, the animals subjected to the test, showed the necessity for the secretion to influence growth, nutrition and development, mental and physical.

Another method of experiment has been the injection of the secretion into the circulation of healthy animals and noting the effect. Further light came from feeding the glands to animals in whom the same or another gland had been removed, and finding the apparent effects.

The principal ductless glands are the *spleen, thyroid, parathyroids, thymus, adrenal, pituitary, pineal* and *gonads*. The liver and pancreas have internal secretions as also the intestinal cells. These have been discussed under those respective headings.

THE SPLEEN (LIEN).

The spleen is a large ovoid body, situated in the posterior part of the abdomen, behind the stomach. In health, it varies in size, but is usually about 5 inches in length, 3 inches wide, and 1 inch thick. It weighs about 5 ounces, is of a purplish-red color, friable, and soft in consistency.

The blood supply of the spleen is very abundant, showing that its function is important, yet its removal has been followed by no permanent bad results. It appears to be an elastic reservoir of blood, undergoing a series of slow contractions and expansions, each lasting about a minute.

The venous blood from the spleen enters the portal vein, goes through the liver and thence to the vena cava. In this venous blood are many leukocytes, but investigators have found out really little about the function of the spleen.

It seems to have some relation to the red corpuscles of the blood,

and their hemoglobin, possibly destroying the corpuscles and transforming the hemoglobin. Removal of the spleen is followed by an anemic condition which lasts but for a short time, with a return to the normal number of corpuscles after some months. Increased amounts of iron are said to be excreted, with a diminution in the amount of bile pigment. After a meal the spleen expands for four or five hours, then returns to its normal size.

The circulation of the spleen is supposed to be maintained by a local arrangement which makes it independent of variations of general blood-pressure.

During fetal life and soon after birth the spleen forms new red corpuscles, but this is not known to continue into adult life. The organ is larger in childhood and gets smaller after puberty. It has been suggested it may be concerned in the production of uric acid. The spleen may become much enlarged and hardened during malaria. It is also credited with influencing the psychic life in the way of depression and irritability.

The structure resembles in some respect that of lymph nodes, and as a whole rather like an enormous group of nodes. It seems to be a filter, taking up dead red cells and particles of foreign matter. It may be a reservoir for red cells. During exercise, it contracts, driving red cells into the circulation.

THE ENDOCRINE SYSTEM.

The glands that are now to be described are supposed to have a definite inter-relation, and are designated as the "endocrine system." The activity of other organs is influenced by the secretions of these glands, the general name of "hormones" being applied to such secretions. Some hormones stimulate, others inhibit activity. No one gland acts alone—but they have a combined action.

The Thyroid.—This is a gland lying on the lower part of the front of the larynx, and upper part of the trachea. (Fig. 309.) It has two lateral lobes connected at the lower part by an isthmus. Each is about 2 inches long, $\frac{3}{4}$ of an inch thick and $\frac{1}{4}$ of an inch wide. It is relatively larger in infants than in adults. It weighs about 1 ounce. It is divided into *lobules* by the prolongation inward of the outer fibrous coat. These in turn are composed of closed vesicles, which are lined with columnar epithelium, secreting a colloid material, a protein containing iodine. It has been found that if the drinking water, and the soil in which vegetables are grown are deficient in iodine, the inhabitants of such region show symptoms of the lack of thyroid secretion. Periodical ingestion of salt containing iodine is effective in practically eliminating the goiters due to the effort of the organism to provide sufficient iodine.

Removal of the thyroid produces a state of chronic malnutrition.

It has, therefore, a profound influence upon nutrition and development. Its secretion acts upon the body cells to increase metabolism.

Normal persons who take thyroid extract have the metabolic function increased with resulting increase in bodily heat and energy, and increased elimination of nitrogen and carbon dioxide. The stimulating effect may be so marked it is well described as a "kinetic urge" or desire for activity. Perhaps the most marked change is the increased heat, which may well indicate that the secretion's normal function is the stimulation or regulation of metabolism with all that this implies.

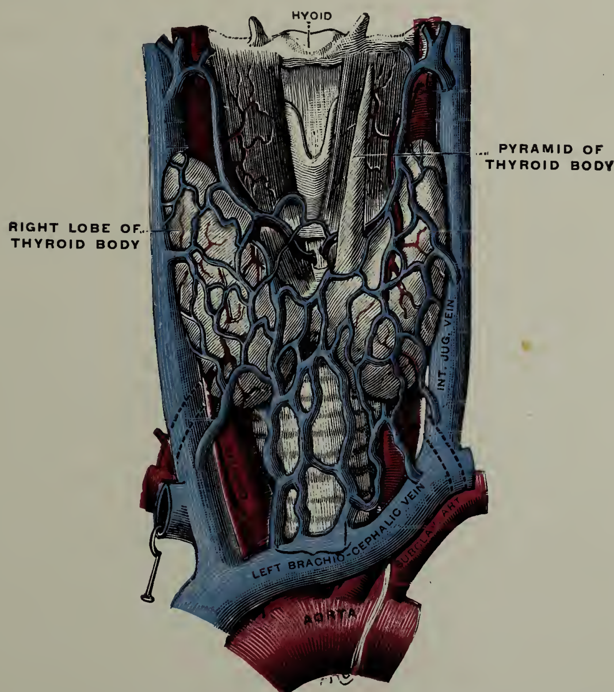

Fig. 309.—The thyroid body and the related bloodvessels. (Testut.)

Abnormal growth of the thyroid produces *hyperthyroidism, toxic goiter,* or *exophthalmic goiter,* in which the heart rate is much increased, heat production much augmented, and psychic irritability marked. If the metabolism of normal persons can be indicated by "40," that of such subjects might be indicated by "75."

Where there is atrophy of the gland or failure to develop, the condition known as *cretinism* exists. In this there is less metabolic activity than normal, the growth and brain development are stunted, so a child would be of scarcely higher grade than an idiot.

The gland extract administered early enough will start up the processes of normal development, both physical and mental.

When a large part of the thyroid is removed, in adults, the condition known as *myxodema* results. This exhibits lowered metabolism, lessened body heat, increased deposition of fat in the tissues, mental hebetude and lack of activity. These conditions are ameliorated by the administration of regular doses of thyroid extract.

NOTE.—These observations on the effects of the administration of thyroid extract are not to be considered as therapeutic suggestions, but only as illustrations of the action of the secretion.

The Parathyroids.—These are two pairs of round bodies about $\frac{1}{4}$ inch in diameter located above the thyroid gland. Their removal is followed in a short time by death from tetany. The secretion appears to prevent such disorder by regulating the calcium metabolism. In this function, it appears to be closely associated with vitamin D. It is possible the secretion lessens the ability of the organism to take care of sugar. It may prevent or neutralize the accumulation of certain toxic products in the blood.

It is also believed that the parathyroids have to do with the normal irritability of the nervous system and muscles, as well as the normal development of bone.

The Thymus Gland.—This is situated over the upper part of the sternum. Its function is obscure, though it may be concerned with the process of growth. It is said to keep its size and activity until the age of puberty, and then to undergo a gradual atrophy. It is possible there is some reciprocal connection between its function and the development of the reproductive glands.

Adrenal Gland.—The adrenal bodies, or *suprarenal capsules* are conical shaped glands perched on top of the kidneys and imbedded in fat. (Fig. 302.) The gland is divided into cortical and medullary portions, having different functions. Their removal from an animal is followed by its death, which is preceded by great prostration, muscular weakness, and lessening of arterial tone. This fatal result is attributed to the removal of the cortex. Impaired function or disease of the cortex produces a complex known as "Addison's disease." Great muscular weakness, inability to digest food, diarrhea and vomiting, feeble heart action, low blood-pressure, and a bronzing of the skin characterize this condition. There is a loss of tone of all muscles, and, finally, respiratory paralysis. The secretion of the cortex is said to have an inhibitory effect upon the sex glands.

The secretion of the medullary portion, known as *adrenalin*, affects all tissues that are supplied by the sympathetic nerves. It causes contraction of the blood-vessels: increases the power of the heart, slowing its rate; and inhibits movement of the intestine. Later, the blood-vessels dilate in the splanchnic area, so lessening blood-pressure.

Adrenalin appears to have the same effect as that produced by exciting the sympathetic nervous system. After its effects are produced, it disappears from the blood. The secretion, seems to have some relation to the regulation of the sugar supply or sugar consumption of the body.

According to Cannon, strong emotions of fear or anger increase the amount of adrenal secretion. This may mean that when a person is afraid or angry, the increased epinephrin may so stimulate the tonicity of the skeletal muscles, increase the blood going to the nervous system, and make more glycogen available for the muscles, that he will be able to make the natural effort to escape the danger or to protect himself by an offensive.

The Pineal Body or Epiphysis.—This is a very small body which seems to grow to its largest size at about the seventh year, thereafter, gradually lessening and becoming fibrous instead of glandular.

Its secretion seems to cause a lowering of blood-pressure and a lessening of the rate of development of the reproductive organs.

Pathological conditions of the pineal gland apparently result in obesity and too early sexual development. The ancients credited it with being the seat of the human soul. It is located on the under surface of the brain.

The Gonads.—These organs, the testis in the male and the ovary in the female produce a secretion which is necessary to the development of the secondary sexual characteristics. There are also close relations between these secretions and those of other glands that influence nutrition.

Indeed, the testicular and ovarian secretions are believed to have a strong influence on the normal general development of body and mind.

The *primary sexual characteristics* are the ability to develop spermatozoa in the boy, and of ova in the girl, through the maturing of the organs concerned.

The *secondary sexual characteristics,* are the changes that are outwardly visible, as, in the boy the deepening of the voice through changes in the larynx, the growth of hair on the face and about the generative organs, and the development of sexual desire, while in the girl they are the growth of the breasts, the widening of the pelvis, the growth of hair about the generative organs and menstruation.

The Pituitary Body or Hypophysis.—This gland is found at the base of the brain, in the sella turcica of the sphenoid bone. It has an anterior lobe that is fairly large, and a much smaller posterior lobe. The two lobes have very different functions. The secretion of the anterior pituitary has been termed the "key" or "master" hormone. It influences the other endocrine glands in their activities, and is a regenerative factor to them. The general effect of the pituitary seems to be a nervous control and augmentation of the trophic or

metabolic functions, sex development, and those mechanisms by which normal life is maintained.

The slowing down of this influence is noted as the reason for senile changes.

When extracts of the posterior lobe are injected the heart beat is slowed and the blood-pressure raised. It assists in the regulation of carbohydrate metabolism. Most of the involuntary muscles of the body are stimulated as well as some of the glands. The general metabolism is stimulated, particularly through the increased glycogenolysis, by which the glycogen in the liver is made available for use in the muscles.

If the pituitary gland becomes overgrown there is an increased growth of the osseous system. Excessive height in young persons, and increase in the size of the facial bones or those of the extremities in adults, follow this hypertrophy of the gland. Conversely, the lack of the secretion causes dwarfism, underdevelopment of the mind and of the sexual system.

The ductless glands interact on each other. We know little about the chain of consequences that follows stimulation of any gland. That it is extensive, admits no doubt. The injection of pituitary extract counteracts the effects of insulin. Adrenalin diminishes the action of insulin. When the sugar in the blood falls below normal, the adrenals respond by increased secretion which restores the balance. Excessive thyroid secretion diminishes tolerance for sugar. There seems to be coöperation between the adrenals and the thyroid in disturbances of heat production. Precocious development of the sex organs is caused by excessive secretion of adrenalin, while the reverse is due to the absence of thyroid substance.

It seems to be established that the secretions of these organs depend upon an adequate intake of the vitamins and the inorganic salts.

QUESTIONS.

What is an "internal secretion"?

What is the "endocrine system"?

Describe the function of the thyroid gland. What conditions result from a deficiency of its secretion? From an excess?

Describe the functions of the adrenal glands.

Describe the functions of the gonads.

Describe the functions of the spleen.

CHAPTER XVI.

THE REPRODUCTIVE SYSTEM.

A NEW-BORN child has essentially the organs and structure of an adult being. But, there are certain deficiencies of development which are supplied as time goes on.

By the end of the second year the first set of teeth has been mostly acquired. The fontanelles of the skull have closed, and the organs of speech and of locomotion have begun to function by that time. Very evident development of the intellectual centers has occurred, as well as a great increase in the size of the organism. The replacement of cartilaginous material by bone, and the attainment by various bones of their full size, will occupy the years up to twenty. Growth and development proceed, more or less perfectly according to its heredity, the balance of the hormones, and the environment of the child.

But up to the age of puberty it is incapable of reproducing its kind. The object of its preservation and growth, according to the plan of Nature, is not yet achieved.

The term *puberty* indicates that time when the male child can produce *spermatozoa,* and the female child can produce *ova.*

In the temperate clime this occurs from about the twelfth to the fourteenth year. Its onset is characterized by various changes in the body. These changes are the *secondary sex characteristics.* These are due to certain chemical substances developed in the testes and ovaries, to which the name "genital hormones" has been given. It is thought the secretion is from "interstitial cells," but these cells are not always present. The interstitial cells are pigmented yellow, and found between the compartments of convoluted tubules in the testis. Removal of the testes prevents the development of the secondary sex characteristics. Ligation of the vas deferens does not prevent it. From some part of the testis, whether from its substance in the tubules or by the interstitial cells, the hormone is secreted which with the hormone of the anterior pituitary, is responsible, for this phenomenon.

In the boy there is the deepening of the voice, the development of hair about the genitals and in the axillæ and a more rapid rate of growth. Indications of a coming beard are evident, as well as psychic changes in the personality, with the development of sexual desire.

In the girl the mammæ become rounded and fuller, the hips broaden, a growth of hair occurs in the axillæ, and about the genitals, more rapid growth takes place, and menstruation is established.

These are the signs of puberty that show the passing of childhood and the oncoming of adolescence.

For the creation of a new individual an ovum must be fertilized by a spermatozoön, and then nourished for a period of some two hundred and eighty days. This implies *male and female organs of reproduction.*

In the male these are the testicles, the vasa deferentia, the vesiculæ seminales, ejaculatory ducts, prostate, epididymis, Cowper's glands, and the penis. These are the *primary sex characteristics.*

To fulfill their function the spermatozoa must meet and fertilize an ovum.

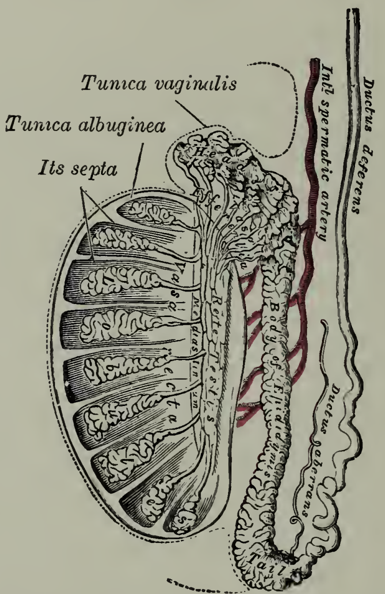

FIG. 310.—Vertical section of the testis, to show the arrangement of the ducts. (Gray.)

Primary Sex Characteristics of the Male.—The essential sex organs are the testes, or testicles. These bodies, during fetal life, are developed in the abdomen. Before birth they enter the inguinal canal with the spermatic cord, descend through the canal and pass out through the external inguinal ring. Thence they descend into the scrotum, where they are suspended by the spermatic cord.

The testes are oblong bodies, 4 to 5 cm. in length, 2.5 cm. wide, and 3 cm. thick. They are covered by three coats, serous, fibrous, and vascular. (Fig. 310.)

In structure they consist of a large number of convoluted tubules, separated by fibrous walls into compartments. Several of these tubules unite into straight tubes, called *vasa efferentia.* A number of these join together to form the duct of the epididymis at the back of the testis. From here arises a thick muscle-walled tube, the *vas deferens,* which leads into the urethra at its prostate portion at the base of the bladder.

Along each side of the bladder, between it and the rectum, are the *seminal vesicles.* These are lobulated, membranous structures, which secrete a fluid to be added to the semen. They are reservoirs for spermatozoa.

Spermatozoa.—These cells are formed in the testes in enormous number. They are long, slender organisms, with a *head, neck,* body, and tail. The head, or nucleus, of the cell is pear-shaped, containing a mass of chromatin which holds the chromosomes. The neck connects the head and body. The rod-like body is followed by a very long tail. The tail acts as a propeller, giving great motility to the sperm cell—this activity lasting several days.

It is estimated that these cells contain 48 chromosomes, which transmit the individual traits of male ancestors. These join with a like number of chromosomes of the ovum, which transmit the traits of female ancestors to the resulting embryo.

According to the sexual activity of the person, these spermatozoa are continually being formed, at varying rates. They are stored in the epididymis and seminal vesicles. They are emitted at the the rate of 250,000,000!

The *scrotum* is a cutaneous pouch, containing the testis and the spermatic cord. Due to the looseness of its structure, the testes can move about freely, thus avoiding pressure.

The *semen* is a fluid, containing the combined secretions of the seminal vesicles, the prostate, epididymis, Cowper's glands, and the spermatozoa. This is emitted during sexual intercourse, through the urethra.

The Urethra.—The urethra is a tube common to the urine and semen. It passes outward from the bladder, through the prostate. A membranous portion, short, and narrow is the most constricted part. This is followed by the penile portion. Cowper's glands (bulbo-urethral) open into it at the beginning of the penile portion. In this latter part it is surrounded by the corpus spongiosum—a spongy mesh of elastic and unstriated muscle tissue which encloses many spaces. These spaces communicate with the veins of the penis. Arterioles also open into the spaces, and the circulation between the two sets of vessels is free. This is true when the muscular walls of the arterioles are in slight tonic contraction. When the walls relax, under the influence of emotion, the spaces are distended with blood, causing the erection of the penis. Several

other structures are to be considered. The *ejaculatory* ducts are formed by the union of ducts from the seminal vesicles and the vas deferens. They begin at the base of the prostate and open into the prostatic portion of the urethra.

The *prostate* gland is a mass of unstriated muscle enclosing numerous branching glands. It is conical in shape, about the size of a chestnut, and lies in front of the rectum, under the symphysis pubis. It secretes the prostatic juice—one of the constituents of semen.

The *spermatic* cord passes through the inguinal canal, escaping through the external inguinal ring, and descends into the scrotum. It consists of arteries, veins, lymphatics, nerves, and the duct through which the testis discharges. The various tubes are held together by areolar tissue, and are covered with serous, muscular, and fibrous coats.

The *vas deferens* is the duct leading from the testis, carrying the secretion of that gland. It continues the canal of the epididymis. It is crooked and cord-like. It joints the duct of the seminal vesicle to form the ejaculatory duct.

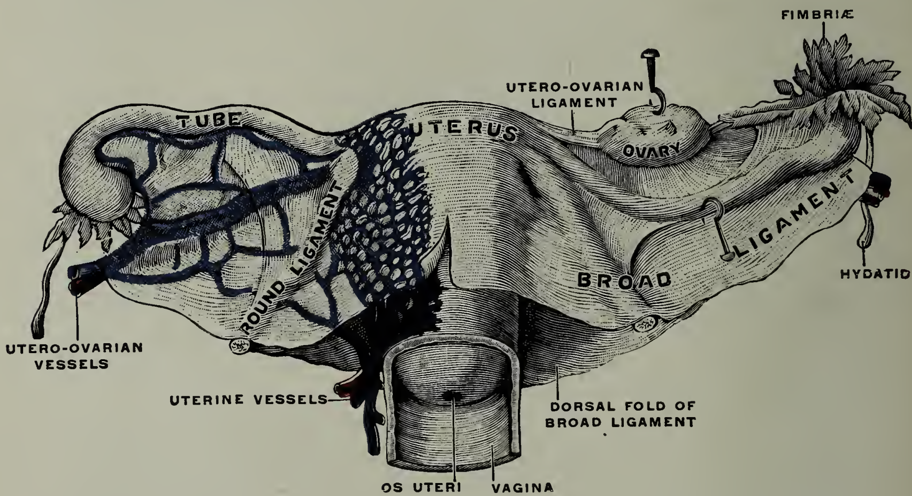

Fig. 311.—The uterus and appendages, front view. On the left side the tube is pulled down, the ovary lifted up. (Testut.)

The Primary Sex Characteristics in the Female.—The female reproductive organs are the vagina, the uterus, the ovaries, and the Fallopian tubes. These are contained within the true pelvis, and communicate with the outside by means of the vagina.

The *vagina* is a canal, partly muscular, partly membranous, that opens at the surface of the perineum and surrounds the neck of the uterus.

The *uterus,* suspended midway in the pelvis by the broad ligament and the round ligaments is a pear-shaped hollow muscular organ, about 2½ inches long. The cavity inside communicates through the cervix (neck) with the vagina below, and with the Fallopian tubes above.

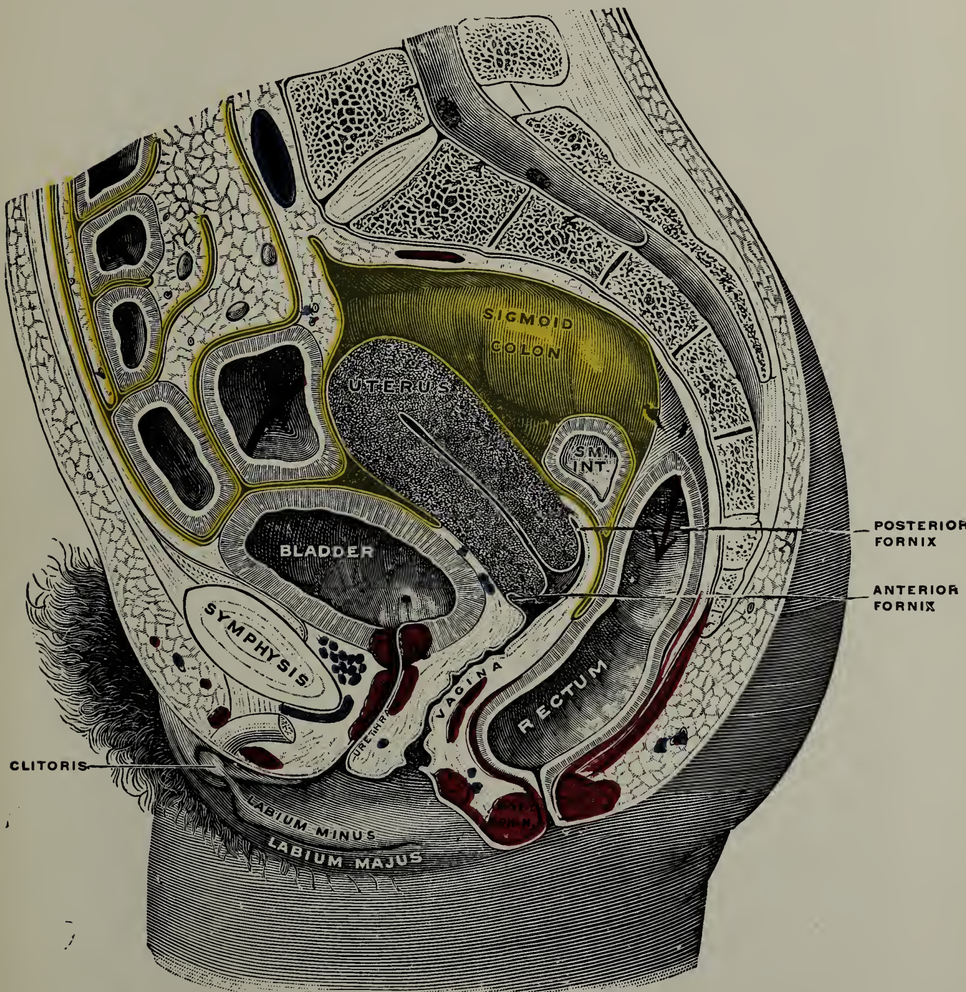

Fig. 312.—Sagittal section of the lower part of a female trunk, right segment. SM. INT., small intestine. (Testut.)

The broad ligament is a wide band of fibrous tissue, passing from the sides of the pelvic cavity in two layers, between which is held and supported the uterus. The ovaries are in its folds on each side of the uterus, with the Fallopian tubes at the upper edges.

The round ligament, passing through the inguinal canal, is attached to the uterus, helping to support it.

The function of the uterus is to receive and contain the fertilized ovum, provide for its nutrition and growth, with its eventual expulsion.

The two ovaries have the appearance of almonds imbedded in the broad ligament.

Their active elements are the Graafian follicles, which every twenty-eight days or so mature and extrude an *ovum*. Between the follicles are the *interstitial cells*. These interstitial cells are supposed to influence the development of the secondary sex characteristics.

While the follicles are present at birth, they do not become functionally active until puberty. Their activity ceases at about the fiftieth year.

The *Fallopian tubes* lie on the upper border of the broad ligament. One end opens into the cavity of the uterus, the other, with moving, fringe-like processes, into the abdominal cavity. As the ova are cast off from the surface of the ovary, they may be caught by these fringes, carried up into the tubes and thence into the uterus. This process is effected by the cilia on the mucous lining of the tube, which always wave toward the uterus.

If no spermatozoa are met during this journey the ovum is not fertilized, but is washed out of the uterus by the ensuing menstrual flow.

Menstruation.—This is a periodic bloody flow, which has been variously interpreted. The most satisfactory theory is that it so roughens the inner wall of the uterus that the fertilized ovum will be caught on it and have the chance to develop a new organism. The ripening of the follicle is the signal for the menstrual flow. If the ovaries are removed menstruation is abolished. It is supposed that they function in turn, each alternate month. During pregnancy no follicles are extruded. The period of lactation is generally free from menstruation. The rhythmical ovulation and menstruation continue from puberty to the *menopause* (about the fiftieth year), when both stop. This provides, after the birth of the last possible child, an "expectancy of life" for the mother sufficiently long for the child to mature and become able to care for himself.

Pregnancy.—If the ovum meets a spermatozoön, either in the tube or ovary, it may be fertilized, with pregnancy resulting.

The *ovum* is spherical, some 0.3 mm. in diameter. It is a mass of cytoplasmic material having a nucleus and a nucleolus. Around the cytoplasm is a clear ring, and that is surrounded by a layer of columnar epithelial cells.

Following the union of the two cells, the fertilized ovum goes into the uterus, settles on the mucous membrane and begins to grow. (For details of development, consult a text on embryology.) At the end of about two hundred and eighty days the uterus has grown enormously, has left the pelvis and gone into the abdomen. By contractions of the uterine muscles, the fully-developed child passes outward, and takes its first breath. This initiates the life of a new individual.

Specialized development of the mammary glands provides milk for its nourishment during the most of the first year.

INDEX.

A

B

C

F

G

N

Q

R

W

Y

Z